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ESSAYS ON THE HISTORY OF AVIATION MEDICINE

by A. A. Sergeyev

U.S.S.R. Academy of Sciences Publishing House
Moscow, 1962

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A. A. Sergeyev

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FOREWORD

The international scientific community has been enriched by the recent publication of A. A. Sergeyev's history of Soviet aviation medicine prior to World War II, and by its present translation into English by the National Aeronautics and Space Administration. An important segment of world aviation medicine has now been documented. It provides a further building block for the clarification of the principles and practice of space medicine.

It is to be hoped that the author, a pioneer in the field, will pursue his stated objective of completing the operational history of Soviet aviation medicine in the World War II period. This would provide an invaluable reference tool for the biomedical community concerned with the ongoing problems of manned space flight.

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INTRODUCTION

Aviation medicine began to develop from the time it became possible to fly in machines that were heavier than air, but some problems that have a direct bearing on aviation medicine began to be studied in physiology long before the development of aviation. One such problem, in particular, must certainly be the effect of reduced atmospheric pressure. This problem began to be studied as early as the 18th century, but particularly energetic experimental research was developed in the second half of the 19th century. It is because aviation medicine has made wide use of scientific achievements in this sphere that it is absolutely essential to give an account of the historical facts concerning study of the effect of rarefied air on the human organism. This is all the more essential since the experimental facts and theoretical views of outstanding Russian physiologists have played an immense part in the development of our knowledge of the effect of altitude.

Essays on the history of aviation medicine covers the period between the inception of the first views on the nature of the effect of reduced atmospheric pressure and the end of the Second World War. The essays deal almost exclusively with aspects of the development of Soviet aviation medicine; the state of aviation medicine outside the USSR is dealt with only in part and the information given applies to the period up to 1930. In this form aviation medicine outside the USSR is presented merely as a background reflecting the specific developmental features of Soviet aviation medicine. The task that I set myself was a narrow one: it was not my aim to give a historical review of world aviation medicine but merely to outline the development of aviation medicine in my country, concentrating attention on the post-revolutionary period.

I realize that in restricting my exposition to the end of the Second World War I have deprived myself of the possibility of dealing with the vast achievements of Soviet aviation medicine in the post-war period but I hope that I may subsequently have an opportunity to bring the work up to date.

I admit that it is another major drawback to my work that the development of Soviet aviation medicine is considered out of context from the development of Soviet medicine as a whole. It would, of course, be more correct to treat the achievements and progress of Soviet aviation medicine as the result of the development of Soviet medicine. The only justification that I can advance is that I was not writing a history of aviation medicine but merely essays which should not be judged by the criterion of profound historical research.

The same considerations to some extent justify the division into periods given in the work, which is not entirely the same as the accepted division in the history of medicine. My division is descriptive merely of separate stages in the development of Soviet aviation medicine and of the part that individual research establishments and personalities have played in that development.

Soviet aviation medicine has come a long way in the last 30 or so years and has encountered many difficulties in so doing. It was necessary to survive the enthusiasms, delusions and plain errors of individual investigators and to overcome and outlive a tendency to defer to all things foreign before Soviet medicine could find that path of its own which it has resolutely pursued for the last 25 years. It is this struggle for a path, this search for a trend that I have attempted to describe in my work.

ESSAY I

BEFORE THE DEVELOPMENT OF AVIATION MEDICINE

Strictly speaking the effect of reduced atmospheric pressure was first studied in detail by Bert (1878).* However even before Bert undertook his strikingly elegant experiments a number of facts were already known that had been established from high mountain ascents, balloon flights and experiments in "pneumatic" chambers, as they were known at the time.

The earliest reference to the unfavorable effect of rarified air is to be found in Aristotle, who asserted that man could not live on Mount Olympus (2985 m) since he would be unable to "breathe air too thin for breathing".**

The earliest and extremely superficial description of the symptoms of mountain sickness is given in the work of Hessner (1540) on his ascent of Mt. Pilat (2132 m).*** Fifty years later Acosta, a Jesuit who accompanied the Spanish army in the South American Cordilleras experienced a number of painful sensations in the ascent of Mt. Pariacacac and came to the following conclusion: "I am convinced that the element of the air is in this place so thin and so delicate that it is not proportioned to human breathing, which requires it denser and more temperate, and I assume that this is the factor that has such a strong effect on the stomach and disturbs all the other functions" (1590).****

The first experimental studies became possible after invention of the barometer by Torricelli (1643) and of the air pump by Guericke (1650).

The experiments of Torricelli and Guericke demonstrated that air has weight and that the atmosphere exerts a pressure of 1.0333 kg per square cm on everything on the earth's surface. These data made it possible to compare

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*P. Bert. La pression barométrique. Paris, 1878.
**A. Haller. Elementa physiologica corporis humani. Berlin, 1788.
***Cited by: P. Bert. La pression barométrique.
****J. Acosta. Historia natural y moral de las Indias, 1590.

man living on the earth's surface with corals and zoophytes living on the ocean bed. Given this situation it was quite natural that some investigators should attempt to study how a reduction in this miraculous pressure would affect the living organism.

The first experimental study of this aspect was carried out by Robert Boyle between 1660 and 1662.* The essence of his main observation was that under conditions of considerable rarefaction the extinction of life coincided with the extinguishing of a burning candle.

"It was not lack of air", stated Boyle, "that would kill the animal but pressure in the thoracic cavity was not in equilibrium with the pressure of the air inhaled and this difference in pressure was so great as to maintain the chest expanded and to prevent its contraction; the lungs and their vessels were so compressed that circulation was impaired (p. 342). . . Following a sudden reduction in pressure in the surrounding air the warm blood of the animals was brought to boiling point or, at any event, so expanded that circulation was impaired, as were all the functions of the organism" (p. 345). (Retranslated from the Russian).

Boyle concluded from his research that "it may be that there is some use for air that we do not yet clearly understand but that makes it so essential to the life of animals" (p. 362). (Retranslated from the Russian).

Giovanni Francesco Cigna** repeated Boyle's experiments and arrived at the conclusion that the harmful effect of rarefied air was mainly due to harmful impurities in the air inhaled.

The experiments of Boyle and Cigna remained unnoticed since few scholars of the time were interested in the study of the air.

Lomonosov (1711 - 1765), the brilliant Russian scientist who was the originator of many sciences, laid the foundations for the scientific study of air. Lomonosov laid the foundations of scientific meteorology and aerodynamics in a number of works including the Free Movement of Air in Mines (1745), A Word on Aerial Phenomena Originating from Electrical Force and Attempts at a Theory of the Elastic Force of the Air (1745). Lomonosov explained a number of such natural phenomena as the aurora borealis, the existence of ascending and descending air currents and the behavior of warm air in rising. In order to raise recording instruments into the upper layers of the atmosphere Lomonosov invented and constructed the first small helicopter in the world in 1754. The

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*R. Boyle. New experiments physico-mechanical, touching the spring of the air. Oxford, 1666.

**G.F. Cigna. De causa extinctionis flammae et animalium in aera interclusorum. Mélanges de philos. et de mathem. de la Soc. royale de Turin. 1760, p. 176.

conference records of the Academy of Sciences for 1 July 1754 contain the entry: "Councillor Lomonosov demonstrated a machine of his invention, which he calls an aerodromic machine, the use of which is that wings moved horizontally in different directions by a clock spring should compress the air (thrust it downwards) as a result of which the machine will ascend into the upper layers of the air with the purpose of studying the conditions (state) of the upper air with meteorological machines (instruments) attached to this aerodromic machine".

Thus the scientific principles of the motion of the air were first laid down in the works of a founder of Russian culture.

Nevertheless all these studies were a long way from the problem of the effect of reduced atmospheric pressure on the human organism and views on the effect of rarefied air were exceedingly confused throughout the 17th and 18th centuries and during the first half of the 19th century.

This confusion of ideas did not however prevent the development of several theories for the cause of mountain sickness. Some of these theories ascribed the development of mountain sickness to harmful vapors, others to the action of subterranean metals, a third group to mysterious poisoning, a fourth group to miasma and so on. There was even an "electrical theory" according to which "electricity caused the blood to flow to the head in the northern hemisphere and to the feet in the southern hemisphere". The same explanation was given for the fact that a mountain sickness case "felt better when lying than when standing".

There was so great a confusion of ideas on the effect of reduced atmospheric pressure at the time that even such major discoveries as Priestley's discovery of oxygen (1777) and Lavoisier's explanation of its role in the process of oxidation (1783) did not help to promote any theory of the effects of rarefied air. Because of this, descriptions of ascents of high mountains such as those given by Borrelli (1671), Scheuchzer (1708)* and especially De Saussure (1787)** contain descriptions of symptoms without any attempt to reveal the mechanism of the effects of rarefied air.

The first theory of the effect of rarefied air was advanced by Haller (1788)*** who was of the opinion that when atmospheric pressure was reduced its mechanical action on the surface of the body was also reduced and as a result the peripheral blood vessels expanded and the blood flowed from the inner organs and the brain to the periphery of the body thus giving rise to anemia of the brain and producing the symptoms of pain at high altitude.

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* Cited by: A. Mosso. Der Mensch auf den Hochalpen. Leipzig, 1899.
** De Saussure. Voyages dans les Alpes. Geneva, 1796.
*** A. Haller. Elementa physiologica. Berlin, 1788.

This theory was universally accepted and confirmations of its correctness are to be found in descriptions of mountain excursions by Humboldt (1802)*, Huga (1839), Wood (1836), Tschudi (1846),** and Baksh (1870).

Exactly the same mechanical explanations of some of the symptoms of mountain sickness can be found in the descriptions of mountain ascents by Russian climbers. Such references can be found in Fedchenko's description of an ascent in the Pamirs***, Kostenko's description of ascents in the Altai and the Pamirs**** and even in Pastukhov's description of an ascent of Mt. El'brus*****.

Therefore up to the middle of the 19th century views on the effect of rarefied air were dominated by a mechanical theory according to which disorders at high altitudes were due to a single factor—the mechanical effect of reduced atmospheric pressure.

2

A new era in man's conquest of the air began in the second half of the 18th century with ballooning. Until quite recently the Montgolfier brothers (1783) have been credited with the construction of the first balloon. Recent research and the earlier investigations of Rodnykh have however led to the discovery of a manuscript by A. I. Sulakadzev entitled Flying in Russia from 906 AD, which described Russian attempts to fly. These attempts include the following description: "In 1731 Kryakutnoi, one of the Governor of Ryazan's officials, made a sack like a large ball, inflated it with evil-smelling smoke, and attached a loop to it in which he sat and the unclean force lifted him above the birches and carried him against a bell tower but he caught hold of the bell rope and thus escaped with his life. The people wanted to bury him alive or burn him, but he was afterwards expelled from the city and went to Moscow".******

Later investigations, especially by Korzinkin (1949), have established the authenticity of Sulakadzev's manuscript and justify the conclusion that 52

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* A. Humboldt. Ann. de chim. et phys., vol. 68, 1838, p. 401.
** Tshudi. Reiseskizzen aus den Jahren 1838-1842. St-Gallen, 1846.
*** A. P. Fedchenko. Izv. ob-va lyubitelei estestv., vol. 26, 1876.
**** Kostenko. Voennyi sbornik, April, 1877.
***** A. V. Pastukhov. Zap. Kavkazskogo otd. Russk. geogr. ob-va, 1893.
****** A. Rodnykh. The history of ballooning and flight in Russia. St. Pb., 1911, p. 11.

years before the Montgolfier brothers a Russian invented and constructed a balloon and also flew in it, thus inaugurating aeronautics.

Nevertheless these experiments remained without application and ballooning began to develop properly only from the end of the 18th century. Despite the already existing balloons fear of the mysterious effects of rarefied air was so great that in 1783 the French physicist Pilâtre de Rozier was refused permission to make a balloon ascent "in view of the unknown effect of altitude on the organism".*

Some time later but still in 1783 Rozier did make an ascent in a crepe paper balloon filled with smoke and hot air. It should be noted that Rozier, who was the first man to leave the ground in a balloon, was a doctor as well as a physicist. He also became the first aeronautical fatality during an unsuccessful attempt to cross the English Channel in 1785.

It should be noted that the first balloon flight for scientific purposes was made in Petersburg on 12 July 1804 by a physicist, Academician Zakharov. In a full report to the Academy of Sciences Zakharov gave a detailed description of his flight which lasted for 3 3/4 hours at an altitude of 2200 m.**

The wide range of Zakharov's research objectives can be seen from this report. He intended to establish "whether liquids evaporated faster or slower, whether magnetic force was increased or decreased, whether the dip of a magnetic needle was increased, whether the heating effect of the sun's rays was increased or decreased, whether the brightness of the colors of a prism was as great, whether or not there was any electric substance and also to make some comments on the effect of rarefied air and the changes that it brought about in man and to conduct various other physical and chemical experiments".

Academician Zakharov remarked of his subjective impressions during the flight that at a height of 2000 m "my hearing was affected, my pulse rate was the same as on land, (namely 82), my breathing was neither faster nor slower at 22 inhalations per minute and in general I was calm and contented and did not experience any changes or disagreeable sensations".

This flight was not independent—Academician Zakharov went up as a passenger. From this time forward however ballooning became popular in Russia and there were many attempts to construct home-made balloons. A field surgeon named Kashinskii was an outstanding enthusiast and should by rights be recognized as the first Russian balloonist since he succeeded in ascending in a balloon of his own construction in September 1805. Kashinskii announced his

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* Cited by: G. Armstrong. Aviation medicine, 1954, p. 7.
** Ya. D. Zakharov. Tekhnol. zhurn., 4 (2), 1807.

flight by the following advertisement: "Field Surgeon Kashinskii who has devoted many years to the understanding of physics and chemistry and who has carried out many preliminary aerostatic experiments . . . will this September . . . undertake an aerial journey at Mr. Zubov's dacha on the Neskuchin estate, for which purpose he has already constructed a large balloon and a parachute".*

Kashinskii's flight actually took place on the 24th September 1805 and was repeated on 1st October. Unfortunately no further information has been found on the fate of the first Russian balloonist.

The first military balloon had been built in Russia by 1812 and was intended for use in the war against the French invaders. In 1828 Madame Il'inskaya ascended to a height of 600 m in a balloon filled with "ordinary straw smoke". In 1846 the writer Kirevskii and later an officer, I. M. Matsnev, constructed balloons and gave demonstration flights. In 1851 the Russian inventor Arkhangel'skii constructed the first guided balloon one year ahead of the French balloonist Giffard. During the Crimean war (1854-1855) Matsnev suggested that the English fleet should be bombarded from a balloon. A standing committee "on the military applications of aeronautics" had been set up in Russia by 1869. The members of this committee included the celebrated Russian scientist Professor Petrov and General Ivanin. The committee laid the foundations for the Russian air force. As a result of the efforts of M. A. Rykachev regular balloon flights were organized in Russia from 1870 onwards.

Doctors played a considerable part in the efforts of Russian inventors to solve aeronautical problems. N. Yudin, a surgeon in the Troitskii uyezd of the Orenburg guberniya, designed the first Russian caloric (heat) motor for a balloon in 1853.

N. A. Arendt, a Simferopol surgeon, was no less of an enthusiast. Arendt made a long experimental study of aeronautics and put forward a number of ideas of undoubted interest in two publications (On Aerial Navigation (1874) and On Aerial Navigation based on the Soaring Principle (1888)).

Arendt concluded from his investigation that attention must be concentrated on "machines heavier than air" rather than on balloons. He was of the opinion that "true flight should be applied to action by which man moves through the air in the direction that he selects". For this he thought that it was essential to have "material equipment or an instrument suitable for flying", "a motive force capable of carrying the aeronaut through the air" and "the skill needed to fly".

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* Cited by: A. Rodnykh. The history of ballooning and flight in Russia, p. 74.

In attempting to solve these questions Arendt "constructed many extremely varied models and carried out many hundreds of experiments" during which he obtained a large quantity of valuable information on how future flying machines should be constructed. Some of the most interesting of his experiments were those in which he catapulted the frozen bodies of birds with outstretched wings to study the properties of soaring.

From the 1880s Russian public opinion became widely interested in aerial navigation. This is shown by the appearance of a number of journals. The Balloonist commenced publication in January 1880. Later journals included The Flyer, Ballooning News and The Ballooning Library.

The great Russian scientist Mendeleev contributed much to the development of Russian ballooning. While still a student Mendeleev aspired to a knowledge of the physics of the high layers of the atmosphere and this interest remained with him throughout his life.

It was not by accident that Mendeleev was interested in the upper layers of the atmosphere. He saw in them a "weather laboratory", "the place where the majority of meteorological phenomena are formed".

Although developing purely theoretical questions Mendeleev maintained close contact with balloonists throughout his life. It was because of these connections that he was able on the 19th August 1887 to make a balloon flight of his own to study a solar eclipse. The flight lasted for 3 hours and 36 minutes and the balloon rose to an altitude of 3000 m.*

Then Mendeleev found a successful solution to safe flights at high altitude by suggesting hermetically sealed cabins. It was only many years later that this idea found practical application in stratosphere balloons and planes.

In describing Mendeleev's part in the development of Russian aerial navigation Fedorov stated at the Mendeleev Congress in 1907: "Aerial navigation was the province of amateurs, mainly people without any scientific training. . . It was only after the famous scientist Mendeleev had pointed out the importance of aerial navigation and had stated that there was need for extremely good and diverse information and for further investigation that the attitude towards aerial navigation changed".**

The first balloon flights were naturally at low altitudes but as balloons were improved the height of ascents increased and the descriptions of

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*D.I. Mendeleev. An aerial journey from Klin during an eclipse. Severnyi vestnik, No. 11, 1877.

**Sanktpeterburgskie vedomosti, No. 62, 1803.

contemporary balloonists contain many accounts of the symptoms of altitude sickness.* Such descriptions can be found in the work of Robertson who ascended to an altitude of 7170 m in 1803, Gay-Lussac who reached 7016 m in 1804 and Glaisher** who reached 8840 m in 1862, among others. All the descriptions of these balloonists are based on the mechanical theory of the effect of rarefied air.

The mechanical theory did however have the practical significance that from the time of its publication doctors concerned with ballooning began to construct pneumatic chambers (pressure chambers) in which they attempted to treat various diseases by rarefied or compressed air.

Junod*** was one of the first to use a chamber of this type. He constructed a copper sphere 1.3 m in diameter which could contain a man and used it both for experiments and for treatment by reduced pressure. Junod established by observing the reactions of his subjects that a reduction in pressure by one quarter of an atmosphere gave rise to the following symptoms: blocking of the ears, increased respiratory and pulse rate, blood flow to the head giving rise to a sensation of burning in the face, expansion of the gases in the body cavities and reduction in the secretory activity of the salivary glands and kidneys.

This equipment can in practice be treated as the first pressure chamber for human beings. Pravaz**** and Vivenot***** subsequently carried out experiments in the same chamber. These investigators also noted quickening of the pulse and breathing and reduction in the vital capacity of the lungs in rarefied air.

Katolinskii (1862) produced the first Russian summary of literature on physiological phenomena in rarefied air. He stated that reduction in barometric pressure was followed by "speeding-up" of respiration, quickening of the heart beats, loss of appetite, nausea, vomiting, an increased sensation of thirst, reduction in muscular strength, general debility, headaches, sleepiness and frequent fainting. In Katolinskii's opinion all these phenomena were due solely to the mechanical effect of reduced pressure. He calculated that an individual 170 cm tall experienced an atmospheric pressure of up to 15 500 kg at sea level and concluded that this pressure was reduced to 10 636 kg at an altitude of 3000 m

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* Cf. A.S. Shor. Aerial navigation in life. St. Pb., 1912.

** J. Glaisher. Lancet, 1862, p. 559.

*** Th. Junod. Arch. gén. de med., vol. 5, ser. 9, 1835, p. 157.

**** Ch. Pravaz. Compt. rendu de la Soc. biol., vol. 7, 1838, p. 283.

***** R. Vivenot. Arch. für path. Anat. und Physiol., 19 (5-6), 1860.

and to 6424 kg at 7000 m. This circumstance (reduction in the weight of the atmosphere) was the cause of all the physiological and pathological processes that developed at high altitude.

Nevertheless a number of successes in the treatment of certain diseases by rarefied and compressed air aroused the interest of L. N. Simonov, a Petersburg doctor, who constructed a special pneumatic treatment center in 1866 on the Vasil'ev Island in Petersburg where various diseases were treated in comfortable pressure chambers. In 1876 Simonov published a weighty volume entitled Air Therapy. Compressed and Rarefied Air from the Physiological Point of View. In this book Simonov considered his physiological observations exclusively from the point of view of the mechanical effect of reduced and increased atmospheric pressure.

Simonov wrote: "In rarefied air . . . the capacity of the lungs should be reduced, the mobility of the chest restricted, the filling of vessels with blood and their emptying should be increased in the lungs and the organs of the chest in general, in the skin and in mucous membranes accessible to the direct effect of altered air pressure, while the density of the tissue should, on the other hand, be decreased. The filling of the vessels with blood and their emptying should, conversely, be less pronounced in organs and parts of the body removed from this influence. Intake of oxygen and elimination of carbon dioxide are reduced, the pulse quickens and the work of the heart is increased. Finally the nervous system should show signs of stimulation rather than of sedation."

It has to be admitted that other Russian investigators showed a tendency to treat the effect of reduced atmospheric pressure solely in terms of mechanistic concepts. Thus, for example, Drozdov and Bochechkarov treated the breathing of rarefied air purely from this standpoint in their work with a Waldenburg apparatus in 1875.

3

By the beginning of the second half of the 19th century Russian investigators had made a number of extremely important discoveries which although they bore no direct relationship to the pathogenesis of mountain or altitude sickness considerably expanded ideas of the reactions of the organism to inadequate oxygen supply.

The first discovery was made by the father of Russian physiology, I. M. Sechenov, who first established the state of gases in the blood in 1859. In The Gases in the Blood (1907) Sechenov criticized Ferke's experiments (1857) and gave the results of his own studies of gases in the blood of normal and suffocated animals. These studies showed that the normal arterial blood of a dog contained between 16.41 and 15.05% of oxygen, between 1.20 and 1.192% of

nitrogen, between 30.66 and 28.27% of free carbonic acid and between 2.54 and 2.32% of combined carbonic acid.

It was also established in experiments in which dogs were suffocated that oxygen disappeared almost entirely (down to "traces") from the blood and the alveolar air under these conditions and that the carbon dioxide content of the blood increased considerably.

When carrying out these experiments Sechenov, as a careful observer, did not fail to notice one fact of extreme importance, namely that in death by suffocation loss of function of the various divisions of the central nervous system occurred at different times and followed a definite sequence. Sechenov noted, for example, that trigeminal nerve reflexes (mainly corneal reflexes) disappeared before loss of function in the vasomotor and respiratory centers. This fact, which indicated a sequence in elimination of the functions of various divisions of the central nervous system in acute hypoxia remained unnoticed for almost 75 years but became of overriding significance with the development of evolutionary concepts in physiology.

The second discovery was made by Z. Yu. Sabinskii who demonstrated in 1865 that when animals were suffocated the spleen contracted and expelled a considerable amount of blood into the blood stream.

Sechenov paid great attention to Sabinskii's experiments. In Nervous Physiology (1866) Sechenov wrote that Sabinskii had proved that "all the blood is completely eliminated from the spleen when a dog is suffocated". Sechenov's interest in these experiments was so great that he carried out a number of additional investigations jointly with Sabinskii. These experiments demonstrated that the introduction of blood from a suffocated dog into the spleen of a normal animal led to contraction of the organ even when the spleen had been denervated. There was however no contraction following the introduction of blood from an animal that had not been suffocated, even when the blood was artificially enriched with carbon dioxide.

Botkin subsequently drew wide general conclusions from this fact, which first established the concept of the spleen as a blood depot. Unfortunately the fact was completely forgotten by Russian research workers and was "rediscovered" by Barcroft in the 1920s.

Another extremely important fact was established at this time. In 1869 V. Manasein of Botkin's laboratory published Materials on the Question of Starvation. The interesting feature of this work is that by studying the survival rate of well-fed and hungry animals in hermetically sealed containers (i.e. under conditions of hypoxia) Manasein established for the first time that starving rabbits survived 2-3 times longer than well-fed rabbits under these conditions.

Work carried out in the Physiological Laboratory of Kazan' University under the direction of Kovalevskii is also worthy of great attention. In the 1860s and 1870s this laboratory was mainly concerned with studying the reactions of the living organism in asphyxia. It was shown in the laboratory that pressure within the eye was reduced in asphyxia (Adamyuk, 1867), that arterial pressure was increased (Kovalevskii and Adamyuk, 1868) and that the eyeball was dilated (Navalikhin, 1869). Other works from the laboratory included Gvozdev's thesis Materials for the Study of Asphyxia (1863) and a detailed paper by Kovalevskii (1871) entitled A Review of Intravital Asphyxial Phenomena which reviewed all the existing data on the effect of hypoxia. Finally, the first lethal concentrations of oxygen in air were produced in this laboratory (Stroganov, 1875): this concentration was 3.54% on average for dogs and 2.33% for rabbits.

Gvozdev's thesis is of particular importance because it first identified asphyxia with hypoxemia. In Gvozdev's own words "asphyxia is deoxidation of the blood, i.e. a condition of the animal organism in which the blood oxygen that is continually used up in maintaining life is for whatever reason not replaced" (p. 8).

Gvozdev's thesis is also of supreme importance because it contains the first classification of anoxial states, which in Gvozdev's view could be brought about by either mechanical or chemical factors. Mechanical factors were involved in anoxial states in which "there was some obstacle within or outside the organism" to the entry of oxygen into the blood. Gvozdev divided these factors into two groups: 1) factors that directly cut off the access of oxygen to the blood (inadequate oxygen content in the atmosphere and the presence of obstructions in the respiratory organs hindering the passage of oxygen into the blood via the lungs) and 2) factors that indirectly terminated the access of oxygen to the blood (changes in the structure or functions of the organs by means of which oxygen entered the blood). Chemical factors were involved in anoxial states in which the blood was subjected to the action of substances that eliminated oxygen from it or converted hemoglobin into other compounds.

Although this was the first classification of anoxial states in the world literature and although it appeared exactly 52 years earlier than Barcroft's classification, its scientific level does not fall short of the present state of our knowledge.

All these studies provide a clear demonstration of the breadth of the approach of Russian authors to the role of oxygen starvation in various pathologic states. There can be no doubt that if the attention of Russian investigators had been directed to the study of reduced atmospheric pressure the theory of hypoxia would have been produced earlier than was actually the case. It was clearly apparent from the research of Sechenov, Sabinskii, Gvozdev and others that at a time when the role of oxygen was still under dispute outside Russia the question had already been solved for Russian investigators. The technical backwardness of Tsarist Russia retarded the development of aerial navigation and this in its turn failed to stimulate Russian scientists to study the effect of

reduced atmospheric pressure. For these reasons alone the honor of producing the theory of hypoxia fell to French scientists.

4

In 1863 Jourdanet concluded from a series of high mountain ascents that the pathogenesis of altitude sickness was based on a single factor—anoxemia. In Jourdanet's opinion each cubic meter of air at high altitude contained less oxygen than at ground level, as a result of which less oxygen passed through the lungs and the blood was unable to take up a sufficient quantity.

Jourdanet's conclusion was of particular value because he demonstrated that oxygen is not merely in simple physical solution in the blood but is chemically bonded with it. This enabled Jourdanet to develop a theory of anoxemia for the first time in his two-volumed work The Effects of Air Pressure on Human Life. High Altitude and Mountain Climates. He wrote: "The symptoms of the notorious mountain sickness (giddiness, vomiting and so on) are nothing other than anemia of the brain due to lack of oxygen in the arterial blood".*

Unfortunately Jourdanet failed to provide experimental proof for this extremely important hypothesis. Nevertheless Bert wrote of it: "We credit him (Jourdanet) with having given a correct explanation of the diseases connected with reduction of barometric pressure since it was he who defined them so precisely and described them by the term anoxemia".**

Bert developed the theory of oxygen starvation with extreme care and in great detail (1878). Bert's simple and precise experiments were in sharp contrast to all that had been done before him and to the extreme confusion and contradictory views that existed. One of Bert's conclusions stands out in particular since it led to final clarification of the pathogenesis of altitude sickness. According to this conclusion all the symptoms of altitude sickness are due exclusively to reduction in partial oxygen pressure in the air. Here is a description of one of Bert's countless pressure chamber experiments: "When air pressure was reduced to 420 mm I began to experience attacks of mountain sickness; these bouts gradually became more intense as the pressure was reduced and produced a feeling of heaviness and debility, neausea, eye strain, general indifference and an insurmountable disinclination to mental activity. When the rarefaction of the air reached a level corresponding to the level on Mt. Blanc

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* D. Jourdanet. Influence de la pression de l'air sur la vie de l'homme. Climats d'altitude et climats de montagne. Paris, 1875.

** P. Bert. La pression barométrique.

I was not in a condition to multiply my heartbeat records by three figures. A little later an uncontrollable convulsive twitch developed in my raised right leg and progressed to the left leg. Blood flowed to my face at this time and the temperature beneath my tongue rose by 0.1-0.2°C."

The experiment was repeated several days later, the only difference being that Bert breathed oxygen for the whole time. Pressure in the chamber was reduced to 304 mm but Bert continued to feel quite normal.

It is extremely difficult to give even a brief account of Bert's main conclusions but the following points can be singled out as being of particular importance:

1) Reduction in barometric pressure affects living creatures solely because of reduction in partial oxygen pressure in the air which they breathe and in the blood which supplies their tissues with oxygen, thus creating a danger of asphyxia;

2) The harmful effect of reduced pressure may be effectively eliminated by breathing air with a higher oxygen content that is sufficient to maintain the partial pressure of this gas at the normal level;

3) Partial pressure is calculated by multiplying the percentage content of the gas by barometric pressure. Reduction in one of these factors may be compensated by an increase in the other;

4) If animals have cavity organs that contained gas in an uncombined form and that are either totally closed or communicating with the atmosphere through narrow apertures, reduction or increase in barometric pressure may have a mechanical effect;

5) All organisms that exist on the earth have become adapted to the partial oxygen pressure with which they live and any reduction is harmful to them.

The correctness of Bert's theory was clearly demonstrated by the tragic flight of Croce-Spinelli, Sivel and Tissandier (1875) in which the flyers, who had only taken a small oxygen supply with them and had economized in its use, lost consciousness at an altitude of 8,500 m. The state of anoxia was so severe that only Tissandier survived.*

This flight convinced everyone of the overriding significance of lack of oxygen in flights at high altitudes and also had the consequence that none dared

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*Cited by: P. Bert. La pression barométrique.

to ascend to a high altitude for the next 20 years. It was not until 1894 that Berson and Süring repeated the attempt and ascended to 7900 m.*

5

This clearly and precisely formulated theory of anoxemia did however have the defect that it failed to allow for the state of the alveolar air. Owing to the presence of residual air and dead space air in the lungs alveolar air has a considerably lower oxygen content than atmospheric air.

Sechenov, who was attracted to the study of the physico-chemical features of gases in the blood from an early stage in his scientific activity, drew attention to this fact. He wrote in his Notes for an Autobiography: "In 1879 . . . I set out to find out how the balloonists in the "Zenith" could breathe at an altitude corresponding to one-third of an atmosphere, i.e. I set out to calculate from available physiological data the extent to which oxygen intake in each respiratory period would be insufficient for respiration."

On 21 December 1879 Sechenov presented a remarkable report to the Sixth Congress of Natural Scientists and Doctors entitled: Data Concerning the Intake of CO_2 and O_2 into the blood under normal breathing conditions and in fluctuating reduction of air pressure. This report was subsequently printed in a slightly modified form in the journal Vrach (The Surgeon) under the title Breathing Rarefied Air. The report was devoted in the main to a profound scientific analysis of the cause of death of the two French balloonists.

Sechenov showed by comparison of the extent of reduction in partial oxygen pressure in the inhaled air and in the alveolar air that death could be due to reduction in partial oxygen pressure in the alveolar air to 20 mm Hg and that "the true reason for the decline in the oxygen content of the blood when breathing rarefied air . . . is to be found primarily in the very rapidly ensuing and very pronounced decline in oxygen pressure in the alveolar air."

In his analysis of this work Koshtoyants has noted quite correctly that Sechenov's research was one of the very first pieces of physiological work to raise the question of the special features of physiological processes in the human organism under conditions of reduced pressure. Sechenov drew on his many years of research on gaseous metabolism to found a new branch of physiology—aviation physiology.**

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*Wissenschaftliche Luftfahren. Berlin, 1899.

**Kh.S. Koshtoyants. Essays in the history of physiology in Russia. Akad. Nauk SSSR, 1946.

However, Koshtoyants failed to notice one very important fact, namely that this paper was not included in the definitive posthumous edition of Sechenov's works published by Moscow University in 1907. The editors (M. A. Menzbir, L. Z. Morokhovets and M. N. Shaternikov) state in their preface that their editorial work was facilitated because Sechenov himself while still alive assembled and prepared the work that he wished to include in the posthumous edition. It is clear that The Breathing of Rarefied Air was omitted from the collected works at Sechenov's own wish, apparently because of his opinion of the paper.

The true reason for this is to be found in another paper included in the complete collected works (1907) and first published in the Pfluger archives for 1880. In this paper (Oxygen Pressure in Alveolar Air under Various Conditions) Sechenov shows extreme regard for scientific accuracy and integrity in acknowledging that he was guilty of an error in his calculations of human oxygen consumption in The Breathing of Rarefied Air. This explains why the paper was not included in the complete collected works.

Sechenov's new calculations given in Oxygen Pressure in Alveolar Air under Various Conditions did not affect his ultimate conclusion. He remained of the opinion that the true reason for the reduction in oxygen in the blood when breathing rarefied air "is to be found primarily in the very rapidly ensuing and very pronounced decline in oxygen pressure in the alveolar air" (p. 226) but supplemented his remark by the following calculations. When breathing atmospheric air at a pressure of 380 mm the percentage content of oxygen in the alveolar air should be reduced to 8% and its partial pressure to 30 mm. Under these conditions stated Sechenov: "breathing is still possible". On the other hand "normal breathing becomes impossible" when atmospheric pressure is reduced to 300 mm, the percentage content of oxygen in the alveolar air is 4.7% and partial oxygen pressure is reduced to 14 mm. Moreover Sechenov's calculations showed under these conditions even intensified respiration would not ensure an adequate supply of oxygen to the blood.

These additions and corrections by Sechenov are in fact the basis on which present-day aviation physiology was subsequently created.

The problem of the effect of rarefied air on the human organism raised by Sechenov was taken up by the important Russian pathologist V. V. Pashutin, who made an extremely detailed analysis of both the mechanical and the chemical effect of rarefied air in his Lectures in General Pathology published in 1881, in which he attached overriding significance to lack of oxygen.

It was in analyzing these questions that Pashutin first introduced the term "oxygen starvation" which excellently describes the nature of the physiological processes that occur at high altitude.

Pashutin made an extremely important contribution to the theory of oxygen starvation when he produced the second Russian classification of the

various forms of anoxial state. This classification, based on the pathogenetic principle, is extremely close to the present-day classification of hypoxia. Pashutin divided the causes of oxygen starvation into two categories: 1) those within the organism and 2) those outside the organism.

The first category included:

1. "Disorder in the supply of oxygen arising from the organs of respiration": a) disfunctioning of the respiratory center, b) changes in the respiratory muscles, c) distortion of the chest, d) tumors and accumulation of fluid in the abdominal cavity, e) inflammation of the abdomen and pleura, f) changes in the respiratory organs hindering the penetration of air into the lungs and g) processes of varying nature in the pulmonary parenchyma reducing the respiratory surface of the lungs.

2. "Changes affecting only the properties of the blood": a) reduction in the quantity of red corpuscles, b) alteration in the capacity of the red corpuscles to absorb oxygen.

3. Slowing down in the circulatory rate of the blood as a result of various types of cardiovascular disease.

4. "Greatly increased oxygen expenditure in the body (muscular effort, feverishness) not matched for some reason by an equivalent rate of supply".

The second category included:

1. When access of air to the respiratory surface of the animal was cut off by purely external influences (drowning, hanging, crushing of the chest and so on).

2. "When the oxygen content of the atmospheric air and equally barometric pressure were below normal".

This was the classification of types of oxygen starvation produced by Pashutin as long ago as 1881. If it is compared with present-day classifications it is impossible not to be struck by the similarity and the profundity of Pashutin's understanding of the essence of oxygen starvation. Only the tissue type of oxygen starvation is not mentioned in Pashutin's classification ("tissue hypoxia") and this is fully understandable since the physiology and pathology of tissue respiration had not been adequately studied at the time.

Pashutin's interest in oxygen starvation gave rise to a number of experimental works on various aspects of the effect of hypoxia. One of the first such works was Al'bitskii's thesis (1885) on The Effect of Oxygen Starvation on Nitrogen Metabolism. Zhirmunskii's thesis The Effects of Rarefied Air on the Human Organism was published in 1884. Zhirmunskii began work on his thesis in 1870 and published his first data, which still showed the signs of a

mechanistic approach, in 1877 but after the publication of Bert's La pression barométrique he fundamentally modified his basic postulates and revised the already completed section of the work. Al'bitskii's Gaseous Metabolism in Animals in a Gaseous Medium Deficient in Oxygen was published in 1904 and Kartashevskii's thesis The Effect of Lack of Oxygen on Metabolism and the Production of Heat in the Animal Organism was published in 1906. In 1908 Kartashevskii also published an experimental study of the effect of environmental temperature on animals in a gaseous medium deficient in oxygen.

This interest shown by Russian investigators in the effect of rarefied air was quite naturally due not to the success of foreign ballooning but to the achievements of Russian balloonists. The necessity for Russian ballooning had been realized in advanced circles of the Russian intelligensia in the second half of the nineteenth century. The idea became a reality in December 1880 when the Russian Technical Society decided to set up a new Department of Aerial Navigation and from this time forward the Society carried out systematic work for many years.

In 1886 the Society acquired its first balloon in Paris, but by 1889 the Petersburg Balloon Park had produced the first Russian balloon. The number of balloonists in Russia increased year by year and by the end of the 90s there was already a need for an all-Russian congress of Russian balloonists and one was held in 1898 in Kiev.

The development of Russian ballooning immediately posed a number of medical and sanitary problems related to the work of balloonists. The first of these problems was the rendering of first-aid and assistance during a balloon flight. This problem was dealt with in Grebenshchikov's A Doctor's Advice to Balloonists published in 1891, in which the author outlined the principles of first-aid treatment for injury, wounds and poisoning during balloon flights.

6

All that has been said is evidence that in old Russia the interest shown by Sechenov in the effect of rarefied air did not die down in the course of time but provided the stimulus for a completely original trend in scientific thought. It is particularly important that this should be stressed since non-Russian physiologists are not in general found to have had a deep interest in the problem, despite Bert's quite exceptional facts.

Some explanation for the lack of interest in this problem may be provided by the objections to Bert's theory advanced in 1883 by Fränkel and Geppert. When testing the oxygen saturation of the blood at a pressure of 405 mm these authors found that the blood contained as much oxygen under these conditions as at ground level. This justified them in asserting that Bert's analytical

methods were not sufficiently accurate.* Subsequently Hüffner (1890) also came to the conclusion that the cause of altitude sickness at altitudes below 9000 m was not to be found in physical or chemical changes in hemoglobin.**

The objections of Fränkel and Geppert and of Hüffner greatly detracted from Bert's theory in the eyes of non-Russian investigators. On the other hand, Russian scholars basing their approach on the data of Sechenov and Pashutin immediately acknowledged that there was a basis for the theory and continued to consolidate it by new experiments.

Interest in the theory ofanoxemia was not revived outside Russia until after the publication of Viaut's research (1890) dealing with changes in the number of red corpuscles and the amount of hemoglobin when some time was spent at high altitude.

The facts described by Viaut were so exceptional and so interesting that a series of high mountain physiological expeditions were organized in a number of countries to carry out new research. One of the first such expeditions was undertaken by Gorbachev (1892) who made a special study of the effect of mountain climbing on blood pressure, respiration, pulse rate, body temperature, "cutaneous and muscular" losses and food intake.

Gorbachev conducted extensive research with healthy young soldiers in the Ala-Tau district. From 5 ascents by the human guinea pigs Gorbachev was able to establish firmly a number of the basic trends in physiological processes at high altitude. He was the first to establish that the effects of high altitude included an increase in blood pressure and pulse rate, an intensification in respiration due mainly to deepening of respiration, reduced output of urine, increased specific gravity of the urine, increased consumption of liquids and some temperature variations.

Gorbachev's investigations prompted him to publish his own high mountain observations and provided the impetus for a number of other Russian doctors. On 9 April 1895 a military surgeon by the name of Tapil'skii presented a paper to the Fergana Medical Society on the effect of the rarefied air and climate of the high Pamirs. In this factual report Tapil'skii gave the facts accumulated in many years of observation of changes in temperature and humidity at an altitude of 3611 m and showed a deep knowledge of the literature on the question. In his treatment of the effect of altitude he dealt separately with the mechanical effect of reduced pressure, the effect of lack of oxygen and the mechanisms of acclimatization to altitude. He gave personal data for reduced coagulation of the blood at altitude, reduction in body weight, reduction

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* Fränkel and Geppert. Über die Wirkungen der verdünnten Luft. Berlin, 1883.

** G. Hüffner. Arch. für Anat. und Physiol., 1890.

in the "fat and muscle layer", in sexual excitability and in the duration of such illnesses as typhus, dysentery, smallpox, cholera, scurvy and sore throat.

Tret'yakov, another military surgeon working in the Pamirs at the same time as Tapil'skii, published experimental studies of the effect of the high Pamirs on the organism in 1895.

Tret'yakov's thesis Mountain Acclimatization (1897) was based on observations made in 1892 and 1893 in the Pamirs, to which a detachment consisting of 500 infantry, 200 Cossacks and a mountain horse artillery battery under the command of Colonel Ionov had been despatched in 1892. The detachment spent some 3 months at an altitude of 3900 m. A force consisting of 172 infantry soldiers, 40 Cossacks, 10 Cossack non-commissioned officers, 10 officers and Surgeon Tret'yakov was left behind to spend the winter at an altitude of 3700 m.

Tret'yakov wrote in his thesis: "At first during our time at the Sha-Dzhan fortress we experienced rapid physical and mental fatigue, breathlessness and palpitation, especially when on the move, or dressing and undressing etc. At first our memories and imaginations were affected . . . After a few weeks all movements became considerably easier."

All these observations interested two more young military surgeons, A. N. Lavrinovich and V. M. Glinchikov, who began to make a systematic study of the blood at high altitude.

Lavrinovich (1899) undertook a mass examination of the blood of Cossacks before ascending the Pamirs and in the Pamirs and Glinchikov (1905) made similar studies of the blood of healthy individuals and patients at the Abas-Tuman spa.

Dr. Munt, the surgeon at the Balloon Training Ground, occupies a special place among the early Russian investigators of the effect of high mountain ascents on the human organism. In 1903 he published a short paper or, more accurately perhaps, communication entitled The Effect of Ballooning on the Organism in the popular scientific journal The Balloonist. In this paper Munt stated that he had made a careful examination of all balloonists to ascend to any altitude since 1897. His examination had covered the following points: 1) vital capacity of the lungs, 2) pneumatometry, 3) blood pressure, 4) sphygmography, 5) dynamometry, 6) "the electric reaction of the organism", 7) sense of touch and of pain and 8) body temperature.

The materials previously obtained had shown that 1) the vital capacity of the lungs underwent "scarcely noticeable" alterations, 2) the strength of the expiratory muscles increased during an ascent, 3) there were "extremely marked fluctuations" in blood pressure, 4) the work of the heart was increased in terms of the rate and strength of the contractions, 5) muscle strength was reduced and 6) body temperature declined.

Munt failed to give any factual material for these assertions but noted that the individual sensitivity of the balloonist to altitude was of immense significance during a flight. At the same time Munt asserted that in flights below an altitude of 3000 m "the lungs, heart, muscles, nervous system and mental faculties were capable of functioning in complete harmony within the limits of normal physiology".

This conclusion based on many years of investigation and on Munt's own flights in balloons was quite unusual at a time when the journals were full of quite anecdotal tales of the lethal effect of an altitude of even 2000 m. Munt must be regarded as the first Russian doctor of aviation medicine and the first to apply physiological research methods to aerial navigation, because of his firm conviction in the correctness of his conclusions, the breadth of the tasks that he set himself, the care with which his research was devised and carried out and the many years that he spent in solving his research tasks. It is however a matter for deep regret that the materials that Munt assembled remained unexamined.

There can be no doubt that Munt's work attracted the attention of many balloonists at the time and that a group of individuals interested in the physiology of high altitude flying gathered round him.

Proof of this interest is provided by a series of articles on physiological subjects published in The Balloonist. For example the second and fourth issues of the journal for 1904 contained articles by Lt. Bol'shev entitled Sensations of a Balloonist During Ascents in Balloons and Kites. The fifth issue of the same journal contained a translated article The Physiological Effects of High Altitudes signed by L. Mischenko. The sixth issue of the same journal printed a paper by Mishchenko entitled The Height of Bird Flight. Breathing Oxygen in a Balloon Ascent. This paper consisted of two parts, the first of which dealt with the data of the zoologist Lucanus on the height of bird flight while the second dealt with the circumstances and conditions of the record flight to an altitude of 10 800 m by Berson and Zuring.

It can be seen that two trends in study of the effect of altitude were beginning to develop in old Russia in the late 19th and 20th centuries, one being concerned with the effect of high mountain ascents and the other with the effect of high altitude flights. It should be stressed that these questions were being studied both in important laboratories and university faculties directed by outstanding Russian investigators and at a lower level by ordinary doctors. The investigators were young military surgeons who had received excellent training from Pashutin's lectures and who were able in their daily work to carry out complicated experimental studies and to contribute much to the development of knowledge on the effects of lack of oxygen.

7

At this time a number of expeditions were also undertaken outside Russia to study the effect of rarefied air. The largest of these expeditions was Mosso's expedition to Monte Rosa (4560 m) in 1893 which consisted of 12 investigators and some Italian soldiers. This expedition occupies a leading place in the history of high mountain ascents for the breadth of the research undertaken and the results obtained, since it enabled Mosso to produce a new theory of the pathogenesis of altitude sickness, the theory of acapnia. Having established that carbon dioxide was washed out of the blood by hyperventilation Mosso concluded that all or a considerable proportion of the symptoms of altitude sickness were due to diminution of carbon dioxide in the organism rather than to lack of oxygen.*

A little later (in 1905) Mosso altered his view and acknowledged that lack of oxygen was the main cause of altitude sickness, although he continued to assert that reduced carbon dioxide pressure in the blood was a concomitant factor in the pathogenesis of altitude sickness.

Mosso's theory of acapnia was rejected by a number of major physiologists immediately after its publication (Zuntz, Loewy and Barcroft). Verigo described it as a "scientific curiosity"** and Haldane and Priestley thought that acapnia was a consequence rather than the cause of altitude sickness.*** As a result of all this the great majority of the physiologists of the time rejected the theory of acapnia.

The theory was resurrected some considerable time later in the 1920s, when one reason for the increased interest in acapnia was the fact established by subsequent research that inhalation of carbon dioxide had a therapeutic effect in a number of cases of respiratory insufficiency. Later in the book we shall have occasion to return to this theory and to consider it in the light of new experimental data.

High mountain expeditions were also carried out by Kronecker, Loewy, and Loewy and Zunta. Finally Zunta, Loewy, Caspari and Müller climbed Monte Rosa in 1901.**** These expeditions, especially the last, yielded new data on

* A. Mosso. Der Mensch auf den Hochalpen. Leipzig, 1899.

** B.F. Verigo. Principles of the physiology of man and the higher animals, vol. 2, St. Pb., 1905.

*** J.S. Haldane and J.G. Priestley. J. Physiol. London, vol. 32: 225, 1905.

**** H. Kronecker. Über die Bergkrankheit mit Bezug auf die Jungfrau. Zurich, 1894; A. Loewy. Untersuchungen über die Respiration und Zirkulation bei Änderung des Druckes und des Sauerstoff-gehalts der Luft. Berlin, 1895; A. Loewy., J. Loewy and L. Zuntz. Pflüg Arch. 66: 477, 1896; N. Zuntz, F. Müller, A. Loewy and W. Caspari. Höhenklimat und Bergwanderungen. Berlin, 1906.

energy expenditure and on the erythropoietic function of the bone marrow at high altitude. The investigators also paid attention to reduction in carbon dioxide pressure in the blood of those examined at high altitude but did not attach great significance to this fact since they were unable to note any parallelism between the phenomenon and the symptoms of mountain sickness.

By 1900 the efforts of many physiologists and doctors over half a century had led to great progress in knowledge of the effects of rarefied air. This progress was utilized in the creation of an elegant theory of oxygen starvation at high altitude, in careful study of the symptoms of mountain and altitude sickness, in attempts to equate the two sicknesses, in explanation of the distinctive role of carbon dioxide in regulating a number of physiological functions and in the design and construction of a number of pneumatic (pressure) chambers for therapeutic and experimental purposes. By this time physiologists already had at their disposal experimental data concerning the effect of reduced atmospheric pressure. As early as 1866 Choveaux had produced the first sphygmographic tracings at high altitude* and in 1869 Lortet had made the first pneumographic tracings.** Later studies included alterations in the partial pressure of oxygen and carbon dioxide in the alveolar air, alterations in the oxygen saturation of the blood and in pulse rate, blood pressure, respiration and body temperature, more exact information on morphological changes in the red blood and the provision of a firm basis for the study of energy losses at high altitude.

All this information shows that by the time that aviation began to develop there was available in physiology extensive information for the time on the effect of rarefied air on the organism and it was no fault of physiology that the nascent subject of aviation medicine was for long unable to make practical application of this information.

8

Strange as it may seem, there was physiological information available at the end of the 19th century on the effect of radial acceleration on the human organism as well as on the effect of reduced atmospheric pressure. The effect of gravity was a problem that had long attracted the attention of a number of investigators, but it was in the main Russian scientists who developed questions concerned with the hydrostatics of blood circulation.

It was apparently members of the staff of the Charity Hospital in Berlin, where the first human centrifuge was constructed in 1818, who made the first

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* Cited by: A. Mosso. Der Mensch auf den Hochalpen. Leipzig, 1899, p. 70.

** P. Lortet. Recherches physiologiques sur le mal des montagnes. Paris, 1869.

attempt to use centrifugal force to disturb the hydrostatics of blood circulation in the brain and thus to influence the course of certain types of mental illness. The centrifuge was a rotating circle and a patient situated on the radius of the circle was exposed to radial acceleration in a caudal-cranial direction. (It should be remembered that "the direction of acceleration" is understood in aviation medicine as the direction of action of the mechanical forces produced in acceleration). There are indications in the literature that this unusual method of effect has had a favorable influence on some types of neurosis and psychoneurosis. It has also been stated that in addition to reddening of the face, petechial hemorrhages of the mucous membranes and the facial skin have been observed in patients treated by the method.*

These facts were in themselves sufficient to indicate that centrifugal force could fundamentally disturb the hydrostatics of blood circulation. Research workers subsequently established that the hydrostatic conditions of circulation could be affected without the use of centrifugal force simply by shifting the body from the horizontal position normal to an animal to the unusual vertical position. Thus Piorri (1826) and later Gall (1832) showed that an animal in a vertical position (head uppermost) died far more rapidly after bloodletting than an animal in a horizontal position, that healthy rabbits in this position normally died within an hour and dogs after several hours and that the animal returned to life when restored to a horizontal position even when it had already stopped breathing. It was also established that the cause of death in this case was acute cerebral anemia.

Although these initial observations were extremely primitive they revealed the significance of such factors as the force of gravity in the process of blood circulation.

Somewhat later the effect of centrifugal force was experimentally studied by Salate (1877 cited by Nemzer, 1892). Salate established that with centrifugal force operating in a cranio-caudal direction rabbits died within 6-15 minutes of acute cerebral anemia. Conversely when the centrifugal force was operative in the caudo-cranial direction dogs died of "immense overfilling of the head with blood" (Mendel, 1884, cited by Nemzer, 1892).

Pashutin (1881) made extensive studies of the hydrostatics of blood circulation when the force of gravity was modified in various ways. He established a number of extremely important facts of fundamental significance for an evaluation of the effect of radial acceleration from a series of experiments on the movement of liquids along inelastic and elastic tubes and from his study of circulation in animals moved from a horizontal to a vertical position.

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*See Nemzer's thesis, 1892.

Pashutin established, for example, that: 1) pressure in the carotid artery was reduced when an animal was placed head uppermost and increased when it was placed head downwards, 2) the amount of blood reaching the heart was reduced when the head was uppermost and increased when it was downwards, 3) the vessels in the upper part of the body "collapsed" with the head uppermost while the veins in the lower part of the body were dilated, 4) the stroke volume of the heart was decreased with the head uppermost and increased with the head downwards, 5) the brain was impoverished of blood with the head uppermost and overfilled with the head downwards, 6) blood pressure in the femoral artery was increased with the head uppermost and decreased with the head downwards, 7) pressure in the jugular vein declined with the head uppermost and increased with the head downwards, 8) pressure in the femoral vein increased with the head uppermost and decreased with the head downwards, 9) respiratory rate was slowed down with the head uppermost and quickened with the head downwards and 10) cerebro-spinal pressure was reduced in the upper part of the cerebrospinal canal and increased in the lower part with the head uppermost.

At the time that Pashutin was engaged in his studies the question was also being studied in Tarkhanov's department. Tarkhanov's colleague Tsybul'skii (1879, 1883 and 1885) was studying what was in essence the same question as Pashutin and his conclusions were, in the main, in full agreement, although Pashutin pointed out some errors in his research method.

This work was continued in Tarkhanov's laboratory by studies of the effect of centrifugal force on circulation. A special "rotating circle" was constructed in the laboratory and an animal was fixed to the radius of the circle with its head pointing towards the center or towards the periphery. With this equipment it was now possible to study the effect of both cranio-caudal and caudo-cranial radial acceleration.

The equipment was used for research mainly by Kuznetsov and Nemzer. Kuznetsov found* that the flow of blood to the head was accelerated by caudo-cranial centrifugal force and that the draining of blood from the head was accelerated by cranio-caudal centrifugal force. In the latter case blood pressure in the carotid artery was considerably reduced. Nemzer, (1892) set himself the aim of studying the nature of gaseous metabolism in rabbits exposed to the action of centrifugal force. He established that there was a reduction in the amount of carbon dioxide secreted by the rabbits with both cranial-caudal and caudo-cranial centrifugal force and that the amount of oxygen absorbed was increased.

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*Kuznetsov. Changes in the morbid anatomy of the brain in persistent hyperemia. Thesis, 1888.

All this research attracted the attention of Bekhterev, who also constructed a "rotating circle" in his anatomical and physiological laboratory and entrusted his colleague E.S. Borishpol'skii with the task of making a more detailed study of the effect of centrifugal force on the function of the central nervous system. Borishpol'skii's research (1896) established the following changes due to cranio-caudal centrifugal force: 1) acute cerebral anemia, 2) reduction in intracranial pressure by 55 mm of water on average, 3) reduction in the excitability of the cerebral cortex, 4) total exsanguination of an operation scar in the cranial region and 5) increase in rectal temperature by an average of 0.3°C. Conversely, caudo-cranial centrifugal force led to great influx of blood into the brain, the edges of an operation wound in the cranial region began to hemorrhage intensively, intracranial pressure increased by 28 mm of water on average, rectal temperature declined by 0.5°C on average and the excitability of the cerebral cortex was invariably enhanced.

Unfortunately there was no further research on the effect of centrifugal force, but what had been done had contributed a great deal to Russian aviation medicine and all the subsequent work carried out in and since the 1930s has been based on the old fundamentals established in Russian physiology at the end of the 19th century.

ESSAY II

THE DEVELOPMENT OF AVIATION MEDICINE — THE FIRST PERIOD

1

There has been a preconceived opinion for many years that the first heavier-than-air flying machine was the work of the American Wright Brothers and that with this machine they became the first persons to fly on the 17th December 1903.

There have in fact been no grounds for this version, which was produced without any justification by individuals who were indifferent and in some cases hostile to the achievements of Russian science and technology.

It has been established beyond all doubt by the research of the last few years that the birth of aviation should be put at a far earlier date and that the honor of inventing the first aircraft must be accorded to the outstanding Russian investigator A. F. Mozhaiskii. For many years the outstanding creative achievement of this Russian inventor was passed over in silence or presented in a distorted light. This is partly to be explained by the fact that there was limited and at times contradictory information concerning Mozhaiskii's activity in both the Russian and the non-Russian press of the end of the 19th century.

Mozhaiskii first conceived the project of constructing a flying machine in 1855. This idea was developed under the influence of a careful study of bird flight and experiments with kites and flying models until in 1877 it was incorporated in a design for a full-size heavier than air flying machine. In 1881 the department of Trade and Manufactures in Petersburg granted the inventor a patent for a "flying instrument"*.

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*Cf.: V. Krylov. A. F. Mozhaiskii. Molodaya Gvardiya, Leningrad, 1951 p. 185.

The patented flying machine included all the main elements of a modern aeroplane: wings, fuselage, power unit, chassis and controls. "It will be seen from the design" wrote Mozhaiskii "that my projected flying machine consists of a boat to hold the engine and people, two fixed wings, a tail that can be raised or lowered to alter the direction of flight upwards and downwards and which carries a vertical plate, movement of which to right and left will steer the machine to the side, a large forward screw, two small screws at the rear of the machine to reduce the dimensions of the forward screw and to execute turns and a wheeled undercarriage beneath the boat to serve as a point of balance for the whole machine and to enable it to run along the ground against the wind with the area of its wings and tail inclined to the horizon and with the leading edge uppermost until it attains the speed necessary for flight ..."*.

On the 20th of July 1882 Mozhaiskii's aircraft, the first in the world, was tested in the presence of many aeronauts. Piloted by I. N. Golubev, a Russian and the first aviator in the world, the aircraft ran along a wooden track, gathered the necessary speed, left the ground and flew over the field for more than 100 sajenes (1 sajene = 2.134 meters. Translator).

The main problem had thus been brilliantly solved — a machine heavier than air had risen into the air. This achievement, which in fact ushered in the era of aviation, was a fitting conclusion to many years of work by the first aircraft constructor in the world. However, the machine was not developed any further and the true development of aviation had to await the beginning of the 20th century.

2

In the first 7 or 8 years of the existence of aviation flights in the crude aircraft of the time demanded no more than courage and bravery from the aviator and this of course was unable to stimulate the development of aviation medicine. It was this that has led American investigators to have a distainful attitude towards the first Russian and French work on aviation medicine and to consider that the subject did not begin to develop until after the First World War. Although this is true of American aviation medicine it is quite untrue of Russian and French aviation medicine. Both in Russia and in France there were printed publications, regulations and instructions before the First World War on the selection, physiology and hygiene of aviators and it can therefore be asserted that aviation medicine began to develop in 1910.

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*Cited in A. F. Mozhaiskii, by V. Krylov (p. 144).

As is sometimes the case in science and technology the same idea, in this case the need to safeguard the health of pilots and rationalize their work, was given real expression almost simultaneously in two countries (Russia and France); the development in Germany came a little later.

Nevertheless the historical facts show quite convincingly that, of these three countries, aviation medicine developed earlier in Russia than in France and Germany.

The interest shown by world opinion in the problems of aviation was due in the first stage of its development exclusively to the progress of French aviation. By 1908 this progress had led to the setting up of a number of records in France by Wilbur Wright, who held the records for the flight of longest duration (2 hr 20 min 23 sec), the furthest flight without landing (124 km 700 m) and the highest flight (115 m). By the end of 1910 all these records had been beaten many times by French pilots. On the 29th of October 1910, for example, Le Blanc set up a speed record (22 m/sec), on the 9th of December in the same year Leganier set up an altitude record (3100 m), on the 18th of December Farman set up a record for duration of flight (8 hr 12 min 47.5 sec) and finally on the 30th of December Tabuto set up a new record for distance of flight without landing of 584.7 km. Young people from many countries who wished to become pilots flocked to the first flying clubs and flying schools that were set up in France at this time.

The progress of French aviation also aroused lively interest in Russian circles. This was particularly reflected in the work of the Aeronautics Department of the Russian Technical Society. This department, which had been set up in the 1880s at the instigation of Mendeleev, had not been particularly active in the first 20 years of its existence but became far more active from 1900 onwards. Other public bodies also became interested in aviation and aeronautics. It is typical that an aeronautics subcommission was set up at the 12th Congress of Russian Natural Scientists and Doctors held in December 1909. Papers were delivered to this sub-commission by Zhukovskii, Kovan'ko, Rykachev and others.

The development of Russian aviation was given great impetus by the setting up of the All-Russian Flying Club on the 25th October 1908. This club, whose members were keenly interested in the development of Russian aviation, publicized its activities widely and attracted a great many young enthusiasts who wished to learn to fly or to build aircraft. In 1909 the club sent a number of young people who wished to become pilots to French flying schools and the first of those who had learned to fly there returned from France in 1910 (Efimov, Popov, Rossinskii, Vasil'ev, Kuzminskii, Matsievich, Rudnev, Utochkin and others).

Now that the club had its own flyers it was able in 1910 to open the first Russian flying school in Sevastopol with the assistance of the "Committee for a Fleet by Voluntary Donations". M.N. Efimov was appointed the first instructor.

It was also at the end of 1910 that the War Department opened the first flying school for officers at Gatchina.

Archive research on the Sevastopol school has yielded some information that suggests that even at that time the doctors of the school gave health and safety advice to the pilots to the extent of their ability and knowledge.

It is, for example, stated in school orders No. 42 of the 18th of June 1911 that: "It has now been finally established by observation that pilots should not under any circumstances take alcoholic refreshments for 12 hours before flying. It is therefore forbidden for there to be any wine at all at the officers' meeting".

The orders for the 11 th of July 1911 state: "The doctors advise student officers to eat not later than 2-1/2 hours before flights since crashing with a full stomach and intestines may lead to rupture of the small intestine, possibly with fatal outcome, even when other injuries are slight"*.

The organization of flying schools was promoted by the particular interest in aviation and its achievements aroused by the three flying weeks in 1910 (25 April — 2 May, 5 — 12 September and 16 — 23 September). These weeks enabled many Russians to see the actual carrying out of an age-old dream of mankind. They were also noteworthy because it was here that Russian pilots and aircraft of Russian construction took part in contests for the first time (the first Russian aircraft "Rossiya-A" was constructed in 1910).

During these three weeks Russian pilots made a number of notable flights and set up records for duration of flight (2 hr 24 min 36 sec), altitude (1200 m), speed (96 km/hr) and load-lifting capacity (216 kg). There was an outstanding flight by Rudnev over the center of Petersburg in which the aircraft twice circled round the cupola of St. Izaac's and another by Piotrovskii and a passenger from Petersburg to Kronstadt.

From this time forward there were countless enthusiasts wishing to learn to fly or turning to the design and construction of aircraft. The latter group included several doctors who became interested in the construction of aircraft. Police permits for the construction of aircraft were issued in 1910 to Dr. Danilevskii (permit No. 41470), surgeon Rotshtein (permit No. 42656) and to S. Mikhailov, a student at the Military Medical Academy, whose permit (No. 45541) was for the construction of "an automatic stabilizer for lateral stability of an aeroplane".

Despite the wide public interest in aviation problems, the actual state of aviation at the time was extremely piteous. Suffice it to say that on the

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*Cited by: I. Spirin. An aviator's notes. Voenizdat, Moscow, 1955 p. 15.

1st of September 1910 there were only 320 aircraft in the whole world, of which France possessed 195, the United States 52, Germany 16, Italy 14, Russia 8, Belgium 7, Japan 5 and Austro-Hungary 2.

3

The 14th of July 1909 should be taken as the day on which Russian aviation medicine was founded. It was on this day that it was suggested at a meeting of the Flying Club Committee that there was a need for the medical examination of pilots. The Committee adopted the following resolution: "This Committee resolves that members of the flying club shall only be permitted to fly if they undergo a medical examination."

When it adopted this resolution the flying club committee had no ready worked out and established standards for the physical condition of pilots and these had to be worked out in the course of systematic examination. Nevertheless the date and the resolution are significant because the need for pilots to be medically examined was realized in Russia earlier than anywhere else.

There are indications that the resolution was the work of Professor Rynin, a most active member of the club and a lively, persistent and energetic man who thought it essential from the very beginning of his interest in aviation that doctors should be called upon to study the physiology and hygiene of flight. His balloon ascent to an altitude of 6400 m on the 21st of September 1910, which was a record in Russia at the time, demonstrated the immense importance of breathing oxygen at high altitude and immediately attracted the attention of many enthusiasts and doctors. Rynin formed a group of doctors interested in aviation.

It was under Rynin's influence that the head physician of the Institute of Means of Communication, N. F. Gun, translated and published Schretter's book on aeronautical hygiene in 1911 and it was also as a result of his influence that the journal The Aeronaut began to publish medical articles from 1911 and that D. V. Feldberg, an ear, nose and throat specialist and one of the first doctors to become a flying enthusiast, produced the first medical examination chart for pilots which was brought into use in 1912.

The close connections that Rynin established with a number of doctors in the initial stages of the development of aviation continued in subsequent decades. It was Rynin who insisted that a course on aerial hygiene should be given in the faculty of aerial communications at the Institute of Means of Communication and he invited Professor Likhachev to deliver this course. It was Rynin who later insisted when the Institute of Civil Aviation was set up that aviation medicine should be included as a subject in the curriculum. Rynin began to study the effect of acceleration in the 1920s and organized a group of doctors (A. A. and M. M. Likhachev, V. M. Karasik and A. A. Sergeev) to study its

effect on the animal organism. Rynin was instrumental in securing the setting up of the Aviation Medicine Unit of the Aeronautics Research Institute in the 1930s. Finally, as soon as the construction of a stratosphere balloon had been suggested, Rynin proposed the setting up of a physiological group to the Society for the Promotion of Self-Defense and the Aero-Chemical Industry and invited M.N. Brestkin, P.I. Egorov, A.V. Lebedinskii and A.A. Sergeev to serve on this group.

All this shows that Rynin was one of the first to understand the role and importance of medicine in the developing profession of flying. By uniting and stimulating the work of the first aviation physicians he played an important part in the history of aviation medicine.

Therefore the foundations of Russian aviation medicine were laid when the flying club passed its resolution on the medical examination of pilots in 1909, although aviation medicine was not in this form a scientific discipline; before it could become a scientific discipline there had to be scientific research and publication. This work developed very rapidly.

An article by Professor Okunev entitled Materials on the Effect of Various Factors in Aeronautics and Aviation on the Ear in Sickness and in Health was published in Archives internationales de laryngologie, d'otologie et de rhinologie in 1910. In this work, which was the first piece of research on aviation medicine, Okunev concluded from a number of experiments and practical observations that only rapid ascents and in particular rapid descents would bring about severe changes in the organs of hearing, that military pilots should not suffer from any illnesses of the organs of hearing, that those employed in aviation should have the right to a special pension and a number of other advantages and that a number of diseases of the organs of hearing should debar individuals from employment in aviation.

This research was followed by more research. An anonymous note entitled Physiological Phenomena at High Altitudes was published in No. 21 of Vestnik vozdukhoplavaniya for 1910, No. 2 for 1911 printed an article by O. Gruzon on the same subject, No. 3 of Vozdukhoplavatel' for the same year carried an article by S.A. Beknev entitled Health and Vision in Aviation, No. 4 of the same year carried an article by the present author under the initials DF entitled Blood Pressure in Aviators and No. 9 printed an article by N. Dampel' entitled Aviators' Sickness. In 1912 the Vrachebnaya gazeta published an article by S.D. Vladychko on the effect of flights on the ear in health and sickness. In the same year the third issue of Voennyi sbornick contained an article by G. Shumkov entitled The Psychophysiological State of Aeronauts during a Flight, which was issued as a separate pamphlet in 1913 by the Voenno-meditsinskii zhurnal. The article was in two parts, the first of which dealt with the effect on man of the motion of the machine during a flight and the second of which dealt with the effect of the environment. The first part dealt with emotional state during a flight, the sensations of motion and direction and air sickness. The second section was devoted to the composition of the atmosphere, the symptoms of mountain sickness and the fatigue syndrome.

All these facts indicate that from the very early stages in the development of Russian aviation there was already a group of doctors who were deeply interested in the problems of aviation and who were attempting to initiate a scientific examination of the physiology and hygiene of flight. Here also, as in the case of high mountain ascents, it was a typical feature that it was ordinary doctors who happened to become interested in this new field of knowledge, rather than major specialists, university departments and laboratories, who took up the study of the scientific problems involved. This inevitably left its mark on the majority of the publications cited above, which showed signs of hastily-drawn conclusions, insufficiently profound scientific analysis of the facts, inadequate understanding of some physical and even physiological phenomena and some tendency to disregard the progress made in physiology in the period before the development of aviation. Nevertheless despite all their shortcomings these first and imperfect studies were so full of enthusiasm and the ardent desire to apply knowledge and effort to development of the new problem that they compel admiration and enthusiasm for the pioneers of the new branch of medicine — aviation medicine.

4

Following the birth of Russian aviation, the great attention paid to it by the War Department and the opening of the Gatchina Flying School for Officers compelled the Military Medical Board to pay some attention to aviation medicine.

From the very first stages in the development of aviation the need for strict selection of candidates for the new profession and for definite health requirements for flyers had been the subject of discussion in the Military Medical Board. Arising from this discussion the War Department issued its first order (No. 481) in 1910 listing "diseases and physical disabilities debarring officers, lower ranks and civilian technicians from service in aeronautical and aviation units". The same order laid down periods of service for officers in these units. The maximum age for service "in aeroplanes" was fixed at 45 and "in balloons" at 58.

In implementation of this order a Medical Flying Commission was set up under the jurisdiction of the Military Clinical Hospital. This commission was headed by the Physician in Chief of the hospital, Dr. Sergiev, and its members were S.M. Poggenpole (therapeutist) E.V. Zelenkovskii (oculist) V.I. Voyachek (ear nose and throat specialist), V.V. Sreznevskii (neuropathologist) and V.N. Derevenko (surgeon). The composition of the commission and the high qualifications of its members indicate that the Military Medical Board attached great importance to its work.

From this time onwards the medical and sanitary requirements of aviation were continually on the agenda of the board's scientific committee.

For example, at a meeting of the committee on the 16th of November 1911 Professor Simanovskii presented a report on the instruments and equipment needed to study the cochlear and vestibular apparatus and draft regulations for their use.

In 1912 the Main Military Medical Board issued circular No. 2462 announcing the regulations for examination of the cochlear and vestibular apparatus in candidates for aviation and balloon units.

At its meeting on the 25th of April 1912 the board's scientific committee approved a resolution on the supply of "instruments and apparatus for studying the effect of flights on the human organism" to the officers' flying school and delegated the preparation of a list of equipment to the commission that had compiled the list of diseases and physical defects that debarred individuals from entering aviation units. The members of this commission were M.N. Rein, N.P. Simanovskii, A.L. Zander, R.R. Vreden and V.M. Narbut.

On the 19th of December 1912 the regulations for examination of the cochlear and vestibular apparatus were modified at a meeting of the board's scientific committee to include a description of the new Galton's whistle and a method of studying acuity of hearing by the reaction to whispered speech. On the 4th of April 1913 the supply of equipment to the officers' flying school for studying pilots in flight was once again on the agenda and it was agreed that the medical unit of the school needed 32 instruments for these purposes. On the 13th of November 1913 the Commission discussed a first-aid kit for pilots and decided on an aluminum box containing appropriate materials and medicaments to be placed beneath the pilot's seat. The plan was approved and an order was given to a factory producing military medical supplies. The factory demonstrated its pilot's first aid kit on the 11th July 1914 and the Committee approved it.

In addition to the work of the scientific committee of the Military Medical Board the War Ministry issued a number of regulations affecting flyers during this period in addition to Order No. 481 of the War Department that has been mentioned above.

In 1912 the War Department issued Order No. 400 on pensions for pilots and pilot-observers. Section 47 of this order provided for a pension of 20% of the pay for service of up to 5 years and an additional 2% for each year of service up to 35 inclusive for service in excess of 5 years. Section 48 provided that in cases of loss of working capacity owing to a crash during a flight the flyer would receive 100% of his pay whatever the period of service.

It would appear that there were many requests for pensions since shortly after publication of Order No. 400 and also in 1912 the General Staff issued instruction No. 880 in which it was stated that "... on the highest authority the officers admitted to aviation detachments and schools should be mainly bachelors".

The functioning of the Military Medical Commission between 1910 and 1913 provided some experience on the examination of pilots and made it necessary to

modify order No. 481. These modifications were embodied in order No. 14 of the War Department issued in 1914 which contained a new list of disqualifying illnesses and physical disabilities.

5

The rise of aviation medicine in Russia and the interest shown by the Main Military Medical Board in the medical and sanitary needs of aviation were due mainly to the progress of Russian flyers.

As early as 1910 (the 22nd of October) Rudnev flew with a passenger from Petersburg to Gatchina covering the 61 km in 56 minutes.

On the 12th of December 1910 Vasil'ev flew from Elizavetpole to Tiflis, a distance of 204 km at an altitude of 1200 m.

On the 23rd and 24th of July 1911 Vasil'ev flew from Petersburg to Moscow covering the 752 km in 24 hr 41 min 14 sec.

On the 29th of September 1912 Abramovich established a duration record for a flight with four passengers (45 min 58 sec).

On the 26th of May 1912 Alekhnovich set up an altitude record (1350 m).

In October 1913 Vasil'ev completed the long flight from Petersburg to Moscow and back in 51 hr 6 min, spending 10 hr 52 min in the air.

On the 23rd of June 1913 Alekhnovich set up a new altitude record (3420 m).

On the 26th of December 1913 Slavorogov established a world speed record for a flight carrying a passenger, covering 250 km in 2 hr 24.5 min. It was also in 1913 that aerobatics were introduced into aviation by Nesterov (1887 — 1914), who became the first man to loop the loop on the 27th of August 1913.

Nesterov's contribution to the history of Russian aviation is of great importance both because he originated aerobatics based on theoretical calculations and extensive studies and because he boldly opposed false theories of flying instruction. As early as 1910 Nesterov wrote: "We are called upon to exercise continuous instinctive control of the aircraft ... Aircraft must be controlled not by instinct but by judgment".*

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*Cited by: N.N. Denisov. Our country — the home of aviation. Voenizdat, Moscow, 1950, p. 68.

Nesterov made a number of extremely important contributions to the methods of flying training and thus improved it.

Nesterov introduced banking turns and discovered the phenomenon of "reversal of controls" by which when banking at above 45° the rudder bar became an elevator and the elevator functioned as a rudder bar. In experimental flights that astonished everyone by their daring and the precision of his calculations Nesterov mastered the spiral glide and turns. His deep turns were similar to those now known as firing turns.

Finally, Nesterov did much to develop long-distance flights. On the 1st of March 1914 he made his first such flight along the route Kiev — Odessa — Sevastopol. The flight took 10 hr 35 min. Two months later on the 11th of May he flew from Kiev to Gatchina, covering the 1250 km in 8 flying hours. Two months later on the 11th July he flew non-stop from Moscow to Gatchina. Nesterov, who was at the front from the very beginning of the 1914 — 1918 war, extended the use of aircraft and introduced such forms of military use as bombing and aerial combat. On the 25th of August 1914 he died a heroic death ramming another aircraft for the first time in aerial combat. It was stated in the report of the enquiry into his death that "... staff captain Nesterov, in conscious disregard of his personal safety, took off, overtook the enemy aeroplane and rammed it with his own machine".

Nesterov's pupil E.N. Kuchen (1890-1917) developed the tactics of aerial combat (attack from below, from the side, after diving and sharp turning into a firing position) and personally short down more than 15 German aircraft*.

Also during the First World War it was a Russian flyer, K.K. Artseulov, who was the first to perform a "corkscrew", a highly skilled flying manouver (the 24th of September 1916).

Russian heavy aviation also began to develop at this time; this type of aviation did not exist anywhere in the world.

In 1912 a group of designers, engineers and workers at the Russian-Baltic factory constructed the first large twin-engined aircraft Grand which carried 7 passengers and developed speeds of up to 80 km/hr. Later four engines were installed in this aircraft; it was named Russkii vityaz and became the forerunner of later heavy multi-engined aircraft. This aircraft first flew on the 27th of April 1913, and in August of the same year with 7 passengers on board it set up a world flight duration record of approximately 2 hours.

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*Cited by: G.V. Zalutskii. Outstanding Russian aviators. Voenizdat, Moscow, 1953, p. 57.

A year later a group of Russian engineers at the Russian-Baltic factory produced a second and improved four-engined aircraft, the Il'ya Muromets. On the 12th of February 1914 the Il'ya Muromets flew for 12 minutes at an altitude of 200 m with 16 passengers on board and in so doing set up a world record for load-carrying capacity. A month later with 10 passengers on board the plane reached an altitude of 1650 m, developed speeds of up to 100 km/hr and remained in the air for 6 hr 33 min.

Another heavy aircraft designed by Slesarev was under construction in Russia at this time. Slesarev's machine, the Svyatogor was designed to stay up longer and to have a greater load-carrying capacity than the Il'ya Muromets.

The first flying boat, the work of the Russian engineer D. P. Grigorovich, the founder of seaplane construction, was built in 1912-1913. In 1914 this flying boat was reconstructed as the M-5 seaplane.

It was also at about this time (1911) that G. E. Katelnikov (1872-1944) produced the first aviation parachute. A non-commissioned officer by the name of Kochmaroi made the first jump with Katelnikov's parachute from the basket of a burning balloon on the 5th of July 1917.

These facts from the history of Russian aviation show that Russia took the lead in solving a number of the pressing problems of aviation technology at a time when it was developing rapidly. The outstanding achievements of Russian scientists and inventors have conferred the title of the home of aviation on our country. It follows naturally that the progress of Russian aviation was bound to excite public interest and to promote the development of aviation medicine in Russia earlier than in any other country.

It can also be asserted from these facts that, from the earliest stages, aviation medicine in Russia took on distinct organizational forms in dealing with the most urgent problem of the time — the selection of pilots. In view of this it is greatly to be regretted that so successful a beginning should have been set back for 7 to 8 years from the start of the First World War.

The extent to which interest in aviation medicine declined in Russia during this period is shown by the fact that only three works appeared in the whole of the 7-8 years and that all of them were concerned with ballooning and not with aviation. An article by E.I. Dombrovskii (The Provision of Medical Assistance to Balloons) appeared in the 6th issue of the Voenno-meditsinskii zhurnal for 1915. In the same year an article by N. Kostyamin (Hygienic Aspects of Aeronautics and Aviation) appeared in the same year in the Encyclopedia of Practical Medicine and in 1917 the Voenno-meditsinskii zhurnal published A.N. Sokolov's article The Occupational Diseases of Aeronauts.

These works failed to contribute anything new to Russian aviation medicine, which was clearly in a state of profound stagnation during the First World War. The revival did not come until after the revolution when, following

a period of searching, enthusiasm and disappointments during the first 10 years of the Soviet State, there was an exceptional development in the 1930s.

6

Aviation medicine developed in France at almost the same time as in Russia. By 1911-1912 France had nearly 500 pilots and had achieved great success in aviation. It was therefore natural that French doctors should be greatly interested in aviation.

It was however not until 1910 that the first French work on aviation medicine appeared. This work by Moulinier was devoted to the effect of flight on the pilot's blood pressure and was of interest and value because Moulinier was the first person in the history of aviation medicine to take medical equipment to an aerodrome and to study pilots before and after flights*.

In 1911 Moulinier, now working with Professor Cruchet, extended his work considerably to study changes in the cardiovascular system.

Moulinier's research attracted the attention of other doctors. For example, Crouzon** thought it worthwhile to include his communication on changes in the blood pressure of two pilots following a flight at an altitude of 2050 m in the reports of the Biological Society of Paris for 1912; Bonnier*** put forward some views on the role of the static sensation in pilots and Marquis published Hygiene pratique de l'aviateur, et de l'aéronaute in 1912****.

These three doctors did not however concentrate on aviation for long. Against the still uncertain background of aviation medicine their role was that of flames that flared up but that died down equally rapidly. The only doctors who continued to study the working conditions of pilots were Cruchet and Moulinier who continued their observations and in 1912 published the first book on aviation medicine with the extremely tendentious title Le mal des aviateurs.

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*R. Moulinier. Gazet. hebd. de Soc. méd. de Bordeaux, vol. 31, p. 457, 1910.

**O. Crouzon. Compt. rend. Soc. biol. Paris, 1912, pp. 530-532.

***P. Bonnier, Compt. rend. Acad. de Sci., 1911, p. 1498.

****R. Marquis. Hygiène pratique de l'aviateur et de l'aéronaut. Paris, 1912.

In this book the authors set out the data yielded by two years of observations of changes in cardiovascular reactions and described a particular morbid condition that developed in pilots after a flight and that was accompanied by a decline in blood pressure, tachycardia, giddiness, an unsteady gait and fainting*.

Despite the fact that it contained a number of points that were open to discussion and others that were incorrect this book was for long popular with French and English students of aviation medicine. The book was translated into English and published in London in 1920 under the title "Air Sickness"** with a foreword by Martin Flack. It should be mentioned that Cruchet and Moulinier considerably extended their knowledge of aviation medicine during these 8 years and extended the framework of their original work.

The English edition of the book aspired to be a handbook of aviation medicine. Its five chapters were devoted to: 1) the physiology of flight, 2) the symptoms of air sickness, 3) training and overstrain of the pilot, 4) aerial hygiene and 5) contraindications against flights. A number of pages were devoted to fatigue, mental and physical strain, an analysis of "air neurosis", the effect of cold, speed and other factors.

It is interesting to note that the idea of using aircraft to evacuate wounded was put forward in France when aviation was in its initial stages. It is true that Dr. Dumaître had suggested the use of spherical balloons to search for wounded on a battlefield as early as 1898 and that in 1910 the Dutch physician De-Moys had suggested that airships should be used for military medical purposes, but these authors had had confused ideas. Nevertheless De-Moys' idea was taken up in France by Test, who suggested that aeroplanes should be used. The idea was first put into effect in 1910 when a woman pilot carried a wounded man by plane.

In 1911 the League of French Women put forward a number of requirements for a medical aircraft and anounced a competition for a design. The only entry for this competition was the work of Julliot and Ribet.

In 1912 a journal article by Périer appeared on this question and in the autumn of 1912 during large-scale manouvers in France an attempt was made to use an aircraft to locate groups of wounded. The results of the experiments were dealt with in an article that Raymond wrote in 1913. This enthusiast for medical aircraft was killed during a flight in 1914.

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*R. Cruchet and R. Moulinier. Le mal des aviateurs. Paris, 1912.

**R. Cruchet and R. Moulinier. Air sickness, its nature and treatment. London, 1920.

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Koschel was the founder of aviation medicine in Germany. It is clear that there must have been a group of enthusiasts active in Germany in 1911 and 1912 prompting public opinion on medical problems in aviation for the German Society of Aeronautics and Aviation to have set up a special committee in 1912 for the medical selection of aeronauts and aviators. Friedlander, Zuntz, Flemming and Koschel were members of this committee. The level and volume of the work carried out by the committee is unknown but in June 1913 Koschel produced a paper entitled The Conditions that the Pilot of an Aircraft should Satisfy in which he advanced a number of points on the need for medical selection of all those entering aviation and aeronautics. Although the paper was published in the second volume of the Jahrbuch der Wissenschaftliche Gesellschaft für Flugtechnik for 1913-1914 it was not until 1916 that there were any official regulations governing the selection of pilots in Germany.

There is little information on the state of aviation medicine in Italy before the First World War. Nevertheless there is reason to consider that here also there were a number of doctors who wished to apply their knowledge to the development of aviation. One of these doctors was clearly Nieddu-Semidei, who published an article in 1911 in the Italian Military Medical Journal (Physical Fitness for the Aeronautic Service).* Another was Falchi, two of whose articles appeared in this journal in 1911 and 1912. One dealt with fitness for flying and the other with analysis of various cases of flying injury, from which Falchi concluded that there was a need to devise ways of protecting pilots from injury.

These three works were clearly chance occurrences arising from chance observations and the authors were clearly not concerned with aviation since they made no attempt to extend their observations and disappeared from the literature as rapidly as they had appeared.

No research on aviation medicine was carried out in either the United Kingdom or the United States before the First World War.

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*A. Nieddu-Semidei. Giorn. di med. mil,, 1911.

The information here given for the first ten years of the existence of aviation has shown that both in Russia and in France and Germany (but earlier in Russia than anywhere else) there were individual enthusiasts who were doctors and who conducted research on the specific features of the work of pilots. Much remained unclear to them. They had no clear understanding of the special features of the work of pilots and aeronauts and they did not know whether to concentrate on physiology, hygiene or occupational pathology. They compensated for the inadequacy of their experimental work by analysis of subjective sensations during flight and this often exaggerated their ideas of the complexity and danger of ascents to altitudes of 2000-3000 m. They were still of the opinion that "all progress is paid for, man pays for his every achievement" (Pachon) and thought that the conquest of the air had brought a "new sickness" to man (Cruchet and Moulinier) and new disorders to the sense organs (Okunev, 1910).

They did not think it possible to make use in their deliberations of the material gathered by physiologists in high mountain ascents. Nor were they able to make use of information obtained from the ascents of spherical balloons to high altitudes since they thought that flying was an entirely separate profession that had nothing in common with ballooning.

Nevertheless their efforts clearly indicated one of the main trends in aviation medicine, namely the need for careful medical selection. It may be considered that this problem of selection was the driving force in the subsequent development of aviation medicine, since all subsequent research on high altitude, high speed, blind and night flying has inevitably led to the same fundamental practical problem — rationalization and improvement of selection methods. All subsequent research in this field and more detailed study compel admiration for the great gifts of the pioneers who succeeded almost intuitively in establishing the main fitness requirements for pilots and thus wrote the first chapter in the new and enthralling book of aviation medicine.

ESSAY III

AVIATION MEDICINE OUTSIDE RUSSIA DURING AND IMMEDIATELY AFTER THE FIRST WORLD WAR (1914 - 1920)

The development of aviation medicine was directly related to progress in aviation technology which aroused public opinion and drew the attention of doctors to the new problems. It must be stressed in particular that Russian flyers played a great part in the development of flying skill and in the achievements of aviation. The great progress that had been made in the development of aviation by the beginning of the First World War is shown by a number of records for duration of flight, altitude and speed.

Of the many long-distance flights in 1913 mention should be made of the flight of Roland Garros from France to Tunis (800 km). Leganier reached an altitude of 6150 m in 1913 and in the beginning of 1914 Linnekogel reached 6500 m. The speed record set up by Prévost in 1913 was 203 km/hr.

All these record flights indicated nothing more than developments in the technique of aircraft construction and were not utilized at the time in aviation practice. The weakness of practical aviation is shown by the fact that the states involved in the First World War entered it with an insignificant number of operational aircraft. Thus, at the beginning of the war France and Germany each had approximately 250 aircraft in service, Russia had 180, the United Kingdom 179 and Italy 84. Almost all these aircraft had a top speed of between 90 and 110 km, a ceiling of approximately 2000 - 2500 m and a load-lifting capacity of approximately 300 kg including fuel supply for 3 to 4 hours flying.

The war revealed the tactical importance of aviation and promoted feverish and increasing production of aircraft by all the combatant states. The figures for aircraft production country by country are as follows:

	1914	1915	1916	1917	1918
France	541	4469	7549	14915	23669
United Kingdom	245	1932	6149	14421	32106
Germany	1348	4532	8182	19746	14123
United States	11	20	83	1807	11916
Italy	-	400	1300	4500	6500

In general the number of aircraft in service with the combatants increased by between 20 and 25 times until by November 1918 it was 26,000 in the United Kingdom, 20,000 in France and 18,000 in Germany.

FRENCH AVIATION MEDICINE

Despite the attempts of individual medical enthusiasts to devote their energies to the study of the occupational features of flying French aviation medicine was in a fairly poor state at the beginning of the war. Although aviation developed at a tempestuous rate and made great advances with respect to the altitude, speed and duration of flight the first doctors concerned with aviation medicine remained observers for a long time. It was not clear how to apply research work to this new and developing profession. The very diversity of the progress led to confusion in medical thought and it was not known whether to devote effort to the effect of altitude, speed or duration of flight. No use was made of the wealth of material accumulated by the high mountain expeditions of Zuntz, Barcroft, Douglas and Duhring in 1910 on Tenerife, of Barcroft in 1911 on Tenerife and in 1912 on Monte Rosa and of Haldane, Douglas, Henderson and Schneider in 1913 on Pikes Peak. The pressing questions remained those of selection and of the causes of crashes, but even here lack of method hindered their study. The only doctors who continued to make observations and accumulate information were the French doctors Cruchet and Moulinier. As a result of all the factors enumerated above no work on aviation medicine was published in any country in the first years of the war.

It was not until 1916 that a revival was noted. In this year the work of Camus and Nepper on the speed with which pilots reacted to visual, auditory and tactile stimuli was published in France. This was the first work in which psychological research methods were applied to pilots. The authors, who investigated the rate of psychic reaction to various stimuli in a large group of pilots and took their flying records into account, concluded that reaction time was shorter in good pilots than in bad pilots.*

The findings of Camus and Nepper were so conclusive that the French Government decided on the 8th of November 1917 to set up a special commission to make psychophysiological studies of pilots.

The work of Camus and Nepper was significant because it initiated a whole new trend in aviation medicine, which gradually developed from pure psychology to psychotechnics and remained a leading trend in aviation medicine for many years.

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*J. Camus and Nepper. Compt. rend. Acad. de Sci., Paris, 1910, p.106.

One feature of 1917 was the simultaneous appearance in almost all the countries in the war (apart from Russia) of a series of works that laid the research basis for aviation medicine. A number of the authors of these works have come to be accepted in the history of aviation medicine as its founders.

The first work of Binet and Garsaux, who drew attention to the physiological problems of aviation, appeared in France at this time.* The physiological trend in French aviation medicine led in 1918 to the setting up of the first low pressure laboratory at Saint-Cyr. The first pressure chamber was installed in this laboratory and the first centrifugal machine was constructed to study the effect of radial acceleration on the pilot. Garsaux, the head of the laboratory, subsequently published a number of interesting papers on the physiology of high altitude and high speed flight.

Garsaux's special contribution was his construction in 1917 of the first apparatus for the automatic supply of oxygen at high altitude, with which an altitude of 12,500 m was achieved in a pressure chamber for the first time. This instrument was the prototype for an infinite series of oxygen apparatuses subsequently produced in various countries.

Another important aspect of Garsaux's activity was his attempt to use carbogen instead of pure oxygen in high altitude ascents. Although he concluded that carbon dioxide should not be added to oxygen his work is important because it shows a revival of interest in Mosso's neglected theory.**

The physiological trend in French aviation medicine promoted a number of articles devoted in the main to circulatory reactions. Work on this subject was carried out both by Cruchet and by Buthier (1918), Josué (1918), Dubus (1919), Villemin (1919) and others. The work of Etienne and Lamy (1918-1919) was particularly typical of the period. In 7 papers published in the course of only two years they demonstrated from orthocardiographic studies that enlargement of the heart was bound to occur in pilots who ascended to high altitudes without oxygen.

All this research was permeated by the basic idea typical of the period that flying was difficult, dangerous and exhausting and that it was bound to lead to premature wearing out of the organism. This idea explains why the majority

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*L. Binet. Rev. gén. de sci. pures et appliqu., Paris, Vol. 28, p. 540, 1917; P. Garsaux. Serv. techn. sect. mil. aeronaut., Paris, 1918.

**P. Garsaux. Compt. rend. Soc. de biol. Paris, vol. 32, p. 643, 1919.

of the papers of the period were devoted to the "air sickness" described by Binet (1917), Cruchet (1918), Ferry, (1918) and others.*

The use of psychological methods suggested by Camus and Nepper was enthusiastically taken up by a number of French doctors. Several of the papers of Gullen, Ambar, Renard, Behague, De Fosset and others showed the interest in these research methods. The selection of French pilots during the war was organized on the following basis: selection points were situated at military hospitals which made laboratories and specialists available. The committees at the selection points were headed by a physician who had received training in aviation medicine and whose responsibility it was to carry out the psychological investigations.

Towards the end of the war this situation was changed when the need was recognized to break away from the hospitals and develop special selection centers staffed entirely by specialists in aviation medicine. The first such center which was opened at Dijon transferred to Paris in the autumn of 1919. In 1920 Bein was put in complete charge of the examination of pilots and it was by his efforts that nine centers for the examination of pilots had been established throughout France by May 1921.

A work by Maublane and Ratié entitled Guide pratique pour l'examen des aviateurs published in 1920 is a most interesting document for the information that it gives on the selection of pilots.** The book is particularly interesting because the authors were two ordinary doctors employed on aviation medicine who worked throughout the war at the flying school at Châtre. They followed the development of aviation medicine and were quick to verify all new proposals on the selection of pilots. They therefore accumulated a great deal of material on which to base the main fitness requirements for pilots which were: 1) age not more than 25, 2) weight not more than 85 kg, Bochard's index not less than 3 and not more than 5, 4) Pignet's formula not above 20, 5) no case history of syphilis, malaria, epilepsy or mental illness, 6) no pathological symptoms of any kind in the cardiovascular system, 7) blood pressure not above 150 mm, 8) no chronic diseases of the lungs and pleura, 9) vital capacity of at least 3000 cc, 10) no chronic disease of the stomach, intestines, liver and kidneys, 11) an

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*See: D. Buthier. Bull. Acad. de méd., Paris, vol. 30, p. 232, 1918; O. Josué, Arch. de med. et pharm mil., Paris, vol. 19, p. 609, 1918; A. Dubus. Compt. rend. Soc. de biol., Paris, vol. 32, p. 1055, 1919; F. Villemin. Compt. rend. Soc. de biol., Paris, vol. 32, p. 696, 1919; G. Etienne and G. Lamy. Bull. Acad. de méd., Paris, vol. 30, p. 151, 1918; G. Etienne and G. Lamy. Compt. rend. Soc. de biol., Paris, vol. 32, p. 652, 1919; L. Binet. Rev. gén. de sci. pures et appliqu., Paris, vol. 28, p. 540, 1917; R. Cruchet. Journ. de méd. de Bordeaux, vol. 19, p. 399, 1919; G. Ferry. Arch. de méd. et pharm. mil., Paris, vol. 30, p. 77, 1918.

**Maublane and Ratié. Guide pratique pour l'examen médical des aviateurs. Paris, 1920.

absolutely healthy and resistant nervous system, 12) visual acuity 1.0 in both eyes, normal color perception and normal optic musculature, 13) normal acuity of hearing measured with an audiometer and normally functioning semicircular canals, 14) reaction time not more than 0.19 sec for visual stimuli, 0.145 sec for auditory stimuli and 0.14 sec for tactile stimuli. Approximately 70% of candidates failed to satisfy all these requirements and of those selected not more than a third became really good pilots.

Therefore, the main trends in aviation medicine (psychophysiological, clinical and physiological) were both outlined and consolidated in France at the end of the First World War and shortly afterwards. Those concerned with the first two trends worked mainly on the selection of pilots while the physiologists worked on the physiology of high altitude and high speed flight.

BRITISH AVIATION MEDICINE

There is nothing to indicate the existence of aviation medicine in Britain before 1917, in which year Anderson published a paper on air crashes and injuries. Between 1917 and 1919 this thoughtful and observant doctor published six papers on this subject and his book Medical and Surgical Aspects of Aviation appeared in 1919.* Since this book was to some extent a landmark in the development of aviation medicine its contents must be briefly considered.

The four chapters of the book dealt with: 1) the selection of candidates for flying training, 2) the psychology of the pilot, 3) aeroneurosis and 4) air crashes. The first two chapters were in essence a repetition of the views of French aviation doctors, but the last two chapters were entirely original.

In the chapter on aeroneuroses Anderson gave the first separate account of various neurotic disorders in pilots, described types of neurotic reaction, gave a clinical picture of aeroneurosis and indicated methods of prevention and treatment. The elegant but completely inappropriate term "aeroneurosis" put forward by Anderson is still widely used by British and, especially, by American aviation doctors.

In the chapter on air crashes Anderson gave the first classification of crashes, examined their causes, described the most typical forms, outlined the organization of first aid on the aerodrome and made a detailed analysis of the specific nature of injuries in air crashes. In this chapter he drew the extremely valuable conclusion that faulty judgment on the part of the pilot was the

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*H.G. Anderson. Medical and surgical aspects of aviation. Oxford, 1919.

main cause of crashes in the majority of cases. He also demanded systematic medical examinations and the study of air crashes and injuries.

Martin Flack, whose work was intimately connected with the functions of the Medical Research Committee set up in 1917, was another important figure in British aviation medicine.

Although not a doctor but a squadron leader, Flack was a member of this committee and has won a place in the history of aviation medicine as the originator of a number of tests for anoxia. One of these tests was the "Flack bag" which was used to test the resistance of pilots to reduction in the oxygen content of the air. Flack thought that his bag could be used to establish the individual ceiling of a pilot.

Of Flack's other works mention should be made of Scientific Tests for the Selection of Pilots, Flying Stress, Aviators' Disease, Causes and Control and Medical Requirements for Aircrew.*

The first of these works is the most important from the point of view of the history of aviation medicine. In it Flack suggests a number of tests of flying aptitude which would, he thought, indicate the probable ability of a candidate to learn to fly. These tests included: 1) holding the breath, 2) a pneumatometer test of the strength and endurance of the respiratory muscles, 3) a test of the stability of the neuromuscular system involving balancing a tuning fork upright on a board and 4) a test of sense of balance.

The works of Anderson and Flack inevitably promoted creative thought among British aviation doctors and a number of articles devoted to various aspects of aviation medicine appeared in 1918. These included an article by McWalter on the physiology of the aviator, an article by Murray on the role of the vestibular apparatus in flying, the work of Panton and Simpson on head injuries in air crashes, an article by Panton on minor complaints of pilots and the work of Rippon on the features of successful and unsuccessful pilots in relation to their temperament and other factors.

The published reports of the Medical Research Committee played an extremely important part at this time. Three reports (Nos. 1, 5 and 6) were published in 1918. Report No. 1 dealt with the oxygen requirements of pilots at various altitudes, Report No. 5 with the pilot's reactions to lack of oxygen and Report No. 6 evaluated the tests of respiration used to determine individual resistance to lack of oxygen.**

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*M. Flack. 1) Nature, 1918, p. 225; 2) Flying stress, London, 1918; 3) Lancet, 1919, p. 210; 4) Proc. Soc. roy. med., London, vol. 14, 1920.

**See: Medical Research Committee, Nos. 1, 5, 6. London, 1918.

All these works show that although British aviation doctors were late in taking up the study of problems in aviation medicine their work immediately showed the features of scientific research although inadequate theoretical grounding was a weak aspect. The main trends in aviation medicine in Britain at the time were: 1) the physiological trend concerned with aspects of the effect of altitude on the organism, 2) the prophylactic trend concerned with air crashes and injuries and the disease rate among aircrew and 3) the clinical trend concerned with the selection and examination of aircrew.

It should be noted in particular that it was at this time that British doctors first raised the question of the need to study fatigue and individual neurotic reactions in pilots, the need to institute strict medical supervision of aircrew and the need to extend and improve the methods of selecting pilots. These questions, which were first raised between 1918 and 1920, pointed the way for the subsequent development of aviation medicine.

ITALIAN AVIATION MEDICINE

Work on aviation medicine in Italy was promoted in the latter years of the war by the efforts of Professor Gemelli who in 1916 set up a special psychological laboratory under the jurisdiction of the Supreme Command on the instructions of the War Ministry.

As the name of the laboratory indicates, its main activity was psychological. Gemelli thought that the psychological examination of pilots was essential both because aviation was a new and exceptional occupation and because flight produced a mass of new sensations even for experienced pilots. The aptitude of a pilot should therefore be determined by the following criteria: 1) ability to comprehend rapidly what was taking place around him and to react quickly by movements of the controls, 2) alertness capable of great concentration and "able to embrace a wide field of vision", 3) ability to memorize quickly and accurately and 4) low excitability without changes in breathing and blood circulation even at times of agitation.*

To this end Gemelli studied simple reaction time, discrimination reaction time, the effect of the emotions on breathing and blood circulation, the volume and level of concentration of attention, pulse, respiration and blood pressure. Particular attention was also paid to investigation of the sense of balance, from which Gemelli concluded that the semicircular canals played no part in the pilot's work.

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*A. Gemelli. Rivista di psicol., Bologna, vol. 13, p. 157, 1917.

The combination of psychological and physiological research carried out by Gemelli justifies the statement that he originated a completely independent trend in aviation medicine - the psychophysiological trend.

Aggazzotti was another outstanding figure. A pupil of Mosso, Aggazzotti had been for some time one of the scientific staff at the high mountain laboratory on Monte Rosa (4560 m) and as early as 1907 he had published an article on changes in the acid-base equilibrium of the blood at high altitude. When he became a collaborator of Gemelli, Aggazotti worked mainly on physiological problems. In a number of articles that appeared in 1918 and 1919 he dealt with the effect of sharp fluctuations in atmospheric pressure on the organism, the treatment of "aviators' disease" (applied by Aggazzotti to the altitude sickness known as hypobaropathy), the effect of flying on the functions of respiration and blood circulation and certain other questions. Aggazzotti devoted some works to emotional states in pilots.*

The psychophysiological trend that Gemelli supported produced a number of successors in Italy, the most noteworthy of whom were Galeotti, Gradenigo, Bilancioni and Saffiotti. In the course of 1918 and 1919 Galeotti published six papers devoted exclusively to psychophysiological studies of pilots.** One of these papers described a special instrument which Galeotti called the "aero-esthesiograph" intended to measure the "muscular" abilities of pilots. In 1919 alone Bilancioni published five papers devoted exclusively to the functions of the vestibular apparatus in pilots and Gradenigo published two papers on "psychological reactivity" in pilots and on psychophysiological research results. Saffiotti's only contribution was a short note on the results of psychophysiological tests.***

A mere list of the printed works shows that Gemelli's psychophysiological trend had firmly captured the attention of Italian aviation doctors. Moreover it clearly satisfied them at that period since all the published work is full of enthusiasm and belief in the correctness of the research results.

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*A. Aggazzotti. 1) Giorn. di med. mil., Rome, vol. 16, p. 183, 1918; 2) Gazz. med. sicil., Catania, vol. 21, p. 104, 1918; 3) Giorn. di med. mil., Rome, vol. 17, p. 218, 1919.

**G. Galeotti. 1) Giorn. di med. mil., Rome, vol. 17, p. 143, 1917; 2) Giorn. di med. mil., Rome, vol. 17, p. 72, 1917; 3) Lancet, 1918, p. 702.

***G. Bilancioni. 1) Giorn. di med. mil., Rome, vol. 17, p. 164, 1919; 2) Policlin., Rome, vol. 26, p. 431, 1919; 3) Gazz. di Osp. Milano, vol. 10, p. 327, 1919; 4) Giorn. di med. mil., Rome, vol. 27, p. 175, 1919; G. Gradenigo. 1) Giorn. di med. mil., Rome, vol. 16, p. 3, 1918; 2) Arch. ital. di otol., Turin, vol. 30, p. 91, 1919; F.U. Saffiotti. Giorn. di med. mil. Rome, vol. 17, p. 180, 1919.

GERMAN AVIATION MEDICINE

Despite all Koschel's efforts, aviation medicine failed to develop in Germany in the first two years of the war. An order of the Air Force Inspectorate on the need to select pilots had the following introduction: "The Inspectorate has hitherto consciously avoided laying down rigid health requirements for pilots. The present order is confined to the main points that military commissions should bear in mind when selecting pilots."* The order goes on to state that a pilot should have a healthy heart, lungs and kidneys, good eyesight and hearing, strong muscles and a healthy nervous system and should be between the ages of 19 and 25.

In the beginning of 1916 the Air Chief of Staff set up a medical department headed by Koschel. Koschel initially set himself the task of discovering the main diseases from which pilots suffered and the factors that made pilots unsuitable for flying duties.

For this purpose he collected the case histories of all pilots pronounced unsuitable for flying duties and found that the reasons given were normally diseases of the nervous system and fatigue. The case histories were, however, of such poor quality that it was impossible to draw any other conclusions.

This study convinced Koschel that the selection and examination of pilots should not be entrusted to ordinary military medical boards but to special boards with the facilities for painstaking and thorough clinical examination. By decree No. 10544/16 of the 23rd of May 1916 the Military Medical Board ordered the formation of special medical boards in all military districts to select candidates for aviation and to make a detailed examination of all pilots pronounced unfit for flying duties by field medical boards. Arising from its examination the board should give its considered opinion on four questions: 1) what the pilot was suffering from, 2) whether suspension from flying duties should be temporary or permanent, 3) whether restoration of working capacity was to be expected and how this was to be achieved and 4) how long this would take.

When these boards had been functioning for several months Koschel already had at his disposal the case histories of 1000 pilots who had been examined, but he failed to obtain the results expected largely because the doctors appointed had no idea of the special features of flying.

In 1917 there was a marked change in direction in German aviation medicine arising from the fact that the Germans had captured Professor Gemelli's entire laboratory with all its apparatus and information after the battle of the River Isonzo. After the work of this laboratory had been studied a

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*Cited by: E. Koschel. Handbuch der ärzlichen Erfahrungen in Weltkriege. Vol. 7, 1922.

number of leading German psychologists and psychiatrists including Stern, Benary and Kronfeld began to use psychological and psychophysiological methods to study pilots.

Kronfeld's method was of particular interest since it permitted the study of a range of mental qualities by a very complicated arrangement (to be described below).* Kronfeld's results were extremely unsatisfactory. Although pilots certainly managed the tests better than non-pilots, age, level of education and extent of training had no effect on the quality of performance in the test.

Benary specialized in the selection of aircraft observers and devised a number of original tests such as the "pathfinding test".**

Koschel, who had become disillusioned with the clinical method, was caught up in the general enthusiasm for psychological methods and began to use them in 1918.

There were therefore two trends in aviation medicine (industrial and pathological and psychophysiological) in Germany in the latter years of the war. Some of the papers that appeared at the time were written by supporters of the two trends.

With the end of the war all scientific research on aviation medicine in Germany came to an end for several years.

AVIATION MEDICINE IN THE UNITED STATES

Aviation medicine developed later in the United States than in other countries because aviation had been treated in the United States as a new form of sport and pilots had been looked on as sportsmen of undoubted courage with no need of medical examination.

It is true that Armstrong *** asserts that regulations governing the medical examination of candidates for employment in aviation had been issued in the United States in 1912, but it is clear that these regulations (if they existed) were not in fact used since Armstrong himself describes the health of United States pilots during the first world war in an extremely unfavorable light on p. 47 of his book.

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*A. Kronfeld. Zeitschr. für Psychol., Leipzig, no. 15, p. 193, 1919.
**W. Benary. Zeitschr. für Psychol., Leipzig, no. 15, p. 161, 1919.
***H. G. Armstrong. Principles and practice of aviation medicine. 3rd edit. Baltimore, 1952.

It was not until 1917 that a few works, more in the nature of reviews than research, were published by doctors serving with the United States squadrons on the Western front. Since these authors were entirely under the influence of the French aviation doctors they showed a quite haphazard interest in various aspects of aviation medicine and rapidly disappeared from the literary horizon. The United States government subsequently suggested to the Institute of Medical Research headed by General Wilmer that it should study "the physical factors affecting flight" and establish physical fitness requirements for flying. In order to solve this task and to become acquainted with the work of French and British doctors on aviation medicine a special commission headed by Wilmer was sent to France in 1917.*

Having become acquainted with French and British and, in part, German aviation medicine the commission drew attention to the fact that, although there was considerable attention to research work, questions concerned with care of the pilot were completely neglected. The commission noted that there were no regulations governing flying time, that some flying conditions that had an adverse effect on the organism were not being overcome, that no systematic check was kept on the health of aircrew, that pilots were unwilling to seek medical assistance and that there was a lack of mutual understanding and close contact between aviation doctors and pilots.

On its return to the United States the commission reported that there was a need to recruit military doctors with sufficient training for work in aviation units and capable of eliminating from American aviation the defects in medical service that the commission had noted in the Allied air forces. The term "flight surgeon" which apparently came into use in March 1918 began to be applied only to doctors working in aviation following special training initially in the air force research laboratory set up in January 1918 and after May 1919 in the School of Aviation Medicine.

Another result of the commission's work was the setting up of the Aviation Medical Research Board on 18 October 1917. The tasks of the Council were defined as: 1) to study all factors capable of affecting the activity of a pilot, 2) to work out and introduce tests to reveal the suitability of pilots for high altitude flights, 3) to carry out experiments and tests aimed at producing oxygen apparatus for high altitude pilots and 4) to act as a standing medical body on all matters concerning the physical aptitude of pilots.

Finally, a third result of the Commission's work was embodied in the first regulations on the physical examination of pilots issued in 1917 and subsequently revised and expanded and published in 1918 in book form.

The work of Wilmer's commission immediately attracted the attention of American aviation doctors and 1918 already saw the publication of 36 papers on

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*Cited by: G. Armstrong. Aviation medicine, p. 32.

the selection of pilots, the use of the Bárány chair test, illusions of counterrotation, unsatisfactory orientation in air, the part played by vision in the sense of balance, the role of the vestibular apparatus and so on. Superficiality in observation and overhasty deduction were features of most of these works.

The physiological trend, which was the most fruitful trend in aviation medicine at the time, was led by such important physiologists as Henderson and Schneider. It was Henderson who, in conjunction with Pierce, designed a special type of respirator (the rebreather apparatus) in 1918 for determining the individual resistance of pilots to lack of oxygen which subsequently replaced the "Flack bag". Schneider soon obtained interesting data with this instrument. He established: 1) that there were individual differences in the ability to withstand oxygen starvation and that those tested could be divided into two groups in accordance with whether or not they lost consciousness; 2) that repeated tests of oxygen deficiency did not increase tolerance, 3) that tolerance was unrelated to physical development, 4) that physical fatigue had no effect on tolerance, 5) that vital capacity, the ability to hold the breath for long periods and the strength of the respiratory muscles played no part in ability to withstand low oxygen pressure.

Schneider also established a number of new facts that were dealt with in his work between 1918 and 1924.* Thus he established: 1) that reduction in alveolar carbon dioxide pressure could already be detected at an altitude of 1220 m, 2) that Cheyne-Stokes respiration frequently developed in pilots at high altitudes, 3) that all respiratory disorders at high altitude were eliminated by breathing oxygen, 4) that the increase in pulse rate was proportional to reduction in the partial oxygen pressure in the air, 5) that breathing oxygen restored the pulse rate to normal, 6) that in hypoxia systolic pressure was increased and diastolic pressure decreased, that venous pressure was also decreased and capillary pressure not affected, 7) that after 40 - 60 min at an altitude of 4500 m there was a discernible increase in the number of erythrocytes and the amount of hemoglobin, 8) that the rate of blood circulation was not increased at high altitude.

Although some of Schneider's points were not confirmed by subsequent research, there can be no doubt that his work contributed much that was new to aviation medicine. His major contribution was his test for estimating the state of the cardiovascular system from variability in the pulse and blood pressure.**

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*See, for example: E.C.Schneider. 1) Journ. Am. med. assoc., vol. 74, 1920; 2) Mil. Surg., 1923, etc.

**E.C.Schneider. Journ. Am. Med. assoc., vol. 74, 1920.

The great interest shown in work on the effect of lack of oxygen was due to the technical improvements in aircraft that enabled Schröder to set up two new altitude records of 8814 m in 1918 and 10,093 m in 1920.

High altitude flights called for the improvement of oxygen breathing apparatus and in 1919 a new type of apparatus using liquid oxygen on the principle of Atend and Highland appeared in the United States. Improvement in Garsaux's apparatus using compressed oxygen led to the production firstly of the American Dreyer type, then of Clark's apparatus and Prout's apparatus.

All these observations show that the main trends in American aviation medicine at that time were: 1) the clinical trend concerned with medical selection and 2) the physiological trend devoted exclusively to the physiology of high altitude flight. Although the psychological trend also existed it was extremely tentative and uncertain and repeated the investigations employed in other countries.

In summing up the development of aviation medicine outside Russia during and shortly after the First World War it is above all necessary to concentrate on the increased interest in the new profession of pilot. This increased interest of doctors in the conditions and specific hazards of flying made it necessary to work out first and foremost some sort of standards for the state of health of pilots. This conditioned the development of the clinical trend, which followed a quite separate source in each country but led by the end of the war to extremely similar results embodied in amazingly similar regulations for the selection of pilots.

The first attempts to unify medical health requirements for pilots were made in 1919. This question was discussed in detail at the first inter-Allied conference of aviation doctors held in Rome between the 15th and 20th of February 1919. This conference worked out a number of basic requirements to be applied to military pilots in all countries. The health requirements worked out by the conference were not, however, put into operation and demands were soon heard in the various countries for "freedom of action" in selecting the method of examination, as a result of which the points adopted by the conference remained a dead letter.

As they extended their clinical studies the aviation doctors of the time arrived at the idea that physical requirements alone were insufficient and needed to be augmented by psychological requirements. However, these wishes were never incorporated in specific instructions. This was largely because investigators had no clear opinion on the psychological qualities to which particular attention had to be paid when selecting pilots or on the methods to be employed.

It was during this period that a firm basis began to be laid for aviation physiology. In the initial stages of development there was an attempt for aviation physiology to follow its own path on the assumption that data obtained by physiologists during high mountain ascents could not be applied to pilots. Some

investigators attempted to strengthen Bert's theory of anoxemia by adducing new data, but they did not succeed in drawing on Barcroft's theory of the respiratory function of the blood (1914). Nor did the aviation doctors of the period cite Haldane's interesting work* on anoxemia, dealing with the results of breathing gas mixtures depleted of oxygen. It was not for several years that this divorce between aviation physiology and general physiology was universally recognized to have been incorrect.

The large number of doctors interested in aviation, the wide range of research undertaken, the novelty of the problems, the complexity of solution and the search for new research methods are all facts that compel the conclusion that it was in this period that investigators in various countries laid the solid foundations on which aviation medicine outside Russia subsequently developed.

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*J.S. Haldane. B.M.J., vol. 2, 1919.

ESSAY IV

ORIGINS OF SOVIET AVIATION MEDICINE

1

The need to create Soviet aviation was one of the most important of the infinite number of tasks facing the young Soviet state after the October Revolution. At the time the Soviet government had at its disposal a few air force units equipped with old and worn-out aircraft including Nieuports, Voisins, Fokkers and Spads, known to the pilots as "flying coffins". There was little in the way of aircraft construction at the time. A number of aircraft factories had been destroyed, others were in territory occupied by the White Guard forces and those that were in Soviet territory were at a standstill owing to lack of raw materials.

Realizing the importance of aviation and the need to develop it in every way possible, the Soviet government and Lenin personally paid great attention to the retention of those already trained, the training of young flyers and the setting up of research laboratories.

As early as the 28th of October 1917 Lenin issued a decree setting up the first Socialist air force unit for the defense of Petrograd against Kerenskii and Krasnov. The Office of Air Force Commissars set up on the 11th of November 1917 had as its tasks the selection of cadres and the collection and protection of the property of the Soviet state in avaition. An order providing for the setting up of aviation and ballooning units was issued on Lenin's initiative on the 20th of December 1917. On the 24th of May 1918 at Lenin's suggestion the main Administration of the Workers and Peasants Red Air Force was set up to unite the country's air forces.

On the 10th of August 1918 a field aviation and ballooning administration of the army (Aviadarm) was set up under the jurisdiction of the Revolutionary Military Council. This measure gave aviation the organizational status of a separate branch of the forces. After Aviadarm had been functioning for several months the Red Army Air Force was set up in 1919. At its inception the force consisted of 62 units with approximately 300 aircraft.

A "flying laboratory" under the scientific direction of N. E. Zhukovskii was set up during the same period (early in 1918) and the Central Institute of Aerohydrodynamics (TsAGI) was set up with Zhukovskii as director at the end of 1918.

The Moscow Flying School, the Gatchina School of Aviation and the Petrograd School of Communist Pilots and Observers were set up in 1918 and the Kiev School of Aviation for the training of technicians and motor mechanics and the Military School of Aerial Surveying and Photography in 1919. Theoretical courses for aviators organized in 1918 gave rise to the Moscow Aviation High School in 1919, which was reorganized in September 1920 as the Institute of Red Air Force Engineers and again in the autumn of 1922 as the Zhukovskii Military Air Academy. Finally, the Air Force Institute for Scientific Testing was set up in 1920.

The Soviet government decided to set up a civil air fleet at the beginning of 1923 and organized the Voluntary Society of Friends of the Air Fleet in March 1923.

All these organizational measures were undertaken under Lenin's direct leadership.

The special Commission for Heavy Aviation (KOMTA) set up by the government at the end of 1919 authorized the Central Institute of Aerohydrodynamics to design heavy aircraft.

The post of Medical Officer was instituted for aviation units in the autumn of 1918 when the medical supervision of aircrews was organized and steps were taken to improve the conditions of flyers. In 1920 the post of Medical Officer was introduced in all air force units on the south-western front. A special sanitorium was also set up for flyers on this front (Strel'tsov, 1946).

This was the beginning of systematic medical study of flying personnel and the inception of Soviet aviation medicine. It was only because of the great attention paid by the Party and government to Soviet aviation in its early stages when it experienced extremely great difficulties that Soviet pilots were able to carry out up to 12,000 sorties during the Civil War and to fly more than 18,000 hours in this period.

By the end of the Civil War the Soviet state had 340 aircraft of 50 different types in service.

When the Civil War was over the Party and government made every effort to create a powerful aircraft industry and to produce Soviet aircraft.* By May 1922 A.N. Tupolev had produced the ANT-1 and in 1923 Polikarpov and Kostkin produced the I-400. It was also in 1923 that three engineers (Aleksandrov, Kalinin and Cheremukhin) constructed the first Soviet passenger aircraft, the AK-1. In the summer of 1924 the AK-1 was already being successfully operated between Moscow and Nizhnii-Novgorod.

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*Cited by: L. Gumilevskii. Wings of the Motherland. Detizdat, 1954.

Other aircraft under design at the same time as the AK-1 included the R-1, the ANT-2 and the MU-1. It was at this time that the design offices of Grigorovich, Polikarpov and Tupolev began to work intensively on the design of Soviet aircraft.

Soviet aviation had a number of major successes to its credit by this period. As early as April 1918 Petrov had made a record flight from Petrograd to Moscow at an altitude of 2500 m in 4 hr 10 min. In January 1921 Belling flew from Poltoratsk to Termez via Kerki covering the 2400 km in 5 days and spending 22 hr 45 min in the air.

In September 1922 Belling flew a round trip Moscow - Smolensk - Gomel - Odessa - Kharkov - Moscow covering 3600 km in 22 flying hours.

In May 1923 Belling flew from Moscow to Bukhara and back with three passengers, covering the 10,570 km in 26-1/2 flying hours.

By 1925 there were already three routes in operation in the USSR: Moscow - Kharkov, opened in 1921, Moscow - Königsberg, opened in 1922, and Moscow - Nizhnii-Novgorod, opened in 1923.

2

Soviet aviation medicine had in practice to start from the beginning. During the First World War the doctors with aviation units had not carried out any research and there had been no summing up of their observations. The blockade and the Civil War made the foreign literature unavailable to Russian doctors. As a result the first Soviet aviation doctor, S. E. Mints, came forward very quietly and uncertainly.

In June 1921 Mints presented a paper to the Fourth All-Russian Air Force Congress on Labor and Health Protection. This paper contained two proposals only: 1) the need for medical study of the life and work of pilots and 2) the need to set up a psychotechnical laboratory to study individual aptitudes.

The reasons given by Mints in support of his proposals immediately attracted the attention of the responsible authorities and the main Administration of the Air Fleet soon provided Mints with the resources to equip a laboratory and set up a permanent committee the members of which were Academicians Lazarev, Kramer, Gannushkin, Golovin, Rozanov, Granovskii and Mints, to study flying and ascents.

Mints began to collect literature on aviation medicine. Unfortunately all that he was able to obtain was the German literature of the latter years of the war. The translated works of Lippman, Zeltz, Benary and Kronfeld strengthened

Mints's belief in the importance of psychological methods and from that time onward he became an organizer of psychotechnics in flying schools.

As senior physician of the school Mints occupied one of the wards beneath the laboratory in a single-storied house allocated to the medical unit of the school of military flyers in a small side street in the old district of Peter's Park almost next door to the famous pre-revolutionary Strel'na Restaurant. A prototype Kronfeld outfit was produced here within a few months with the assistance of an engineer named Gamburger.

A mock-up of a pilot's cabin with controls stood in the middle of a small darkened room. The electric contacts that replaced the control cables enabled the reaction time to each stimulus to be recorded in an adjacent small room on Hipp chronoscopes. The pilot had to look through a panoramic sight at an illuminated moving screen three feet away from him representing the ground from an altitude of 1000 m. On the screen the pilot could see railways, rivers, enemy positions, fortified points, anti-aircraft batteries and troop movements and when a target crossed the thread in the panoramic sight he had to depress a morse key to depict the moment of bomb release. During the test bulbs flashed on to left and right of the pilot in imitation of anti-aircraft fire and the pilot had to take avoiding action. Sometimes the lights were of different colors and it was the pilot's task to react to lights of one color only and not to the others. The whole test was conducted in complete isolation and absolute quiet.

After the test the results were collated and the mistakes made by the pilot and the speed of his reaction to visual stimuli were assessed from the number of targets on the screen that he missed, the number of electric lights lit and the chronoscope readings.

At the same time Mints began to question pilots by Lippman's chart to establish the aptitudes essential to a pilot and he collected statistical material on air crashes between 1920 and 1922. He concluded from an analysis of 364 disasters that 90% were due to the individual features of the pilot and this even further strengthened his conviction in the correctness of his approach. From data for the results of teaching in the flying school for the same years he discovered that only 68% of 260 student pilots successfully completed the course, that 6.5% crashed and that 25.5% failed. In all this he also saw the role of a personal factor (Mints, 1923a).

All these data prompted Mints to present a paper on the 17th of April 1923 to the 25th Joint Open Session of the Military Scientific Committee of the Air Force Staff in which he demanded that the Air Force Staff should pay attention to psychotechnical research in flying schools. As a result psychotechnical laboratories were set up in most flying schools and psychotechnical methods were introduced in the selection of pilots.

As he continued working in his laboratory Mints gradually became acquainted with the foreign literature and his views were subsequently broadened considerably. After studying a report on the health of British flyers for 1921

Mints became convinced that psychotechnics alone were not enough and that the answer was to be found in the overall organization of medical services to flying units. In his report for 1923 Mints already raised the need to set up special medical committees to examine aircrew.

Nevertheless Mints remained devoted to psychotechnics. In 1924 he issued a translation of Kronfeld's article Psychotechnical Tests to Determine Aptitude for Flying without any critical comments.

Nevertheless Kronfeld's conclusion from tests carried out on 30 pilots and 122 pupil pilots were quite exceptional. He found, for example, that: 1) pilots who had had serious crashes and had been pronounced unfit for flying duties for health reasons had worse results in the tests than healthy pilots, 2) that neuropaths needing more than 3 months leave had worse results in most cases although a number of neuropaths had better results than healthy pilots; 3) length of flying service and the number of sorties flown had no effect on the results of the examination; 4) intellectual development also had no effects on the results and subjects with little education gave the same results as subjects with higher education, from which Kronfeld concluded that "the officer was no better than the soldier either absolutely or relatively".*

Mints accepted these results unquestioningly and showed very little deviation from Kronfeld's deductions when he published the results of his own observations in the laboratory of the First High School for Military Pilots (1925b).

This concluded Mints's work and his life. As he came out of his laboratory in 1925 Mints was met by a student whom he had failed, who shot him twice with a revolver and killed him.

3

In evaluating Mints's work in retrospect it must be said that although he confined himself to the introduction of foreign methods in his support for psychotechnical research methods he was nevertheless the first Soviet aviation doctor to indicate the need for medical study of the work and conditions of pilots and in this respect his name will be a notable landmark in the history of Soviet aviation medicine.

It would be quite unjustifiable to reproach Mints for his enthusiasm for psychotechnics since it was a universal feature of the time at which he was working. It was thought at that time that psychotechnics were a scientific discipline that could solve all questions of selection, labor rationalization, the normalization

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*A. Kronfeld. Zeitschr. für Psychol., vol. 15, 1919.

of relaxation and the improvement of health conditions. The amazingly rapid spread of psychotechnics and the general enthusiasm for it had no logical explanation. It is now not difficult to say why this method, which was completely without scientific foundation and was almost amateurish, achieved universal recognition so rapidly. The reason lay partly in its simplicity and primitiveness and the ease with which it could be mastered with a minimum of education and partly in the wide scope which it seemed to present in revealing the personal aptitudes of the individual and the best possible use of these aptitudes in increasing labor productivity, rationalizing labor processes, improving methods of technical education and reducing crashes and injuries.

Could Mints have opposed this trend and not been attracted to it? Could he have refrained from attempting to apply such a method to an unstudied profession?

His enthusiasm was all the more justifiable since it was shared by those more qualified than Mints. Thus, for example, Professor Nechaev concluded in 1923 that a "coefficient of flying aptitude" could be arrived at by investigating seven only of the pilot's aptitudes: 1) adaptation of attention, 2) volume of attention, 3) emotional state, 4) suggestibility, 5) the difference between counting forwards and backwards, 6) the average speed of writing down figures and 7) the average rate of work when relaxed and when subjected to secondary stimuli (Nechaev, 1923).

Nechaev arrived at the "coefficient of flying aptitude" for each individual tested by testing these aptitudes in 33 students at the flying school and in 12 pilots, by assigning a numerical index to each attribute and calculating an arithmetic mean from them. When he verified his estimates against the practical flight evaluation of each of the individuals tested Nechaev found that the estimates coincided "amost 100%" with those of the command and he therefore concluded that a "coefficient of flying aptitude" could be established in the laboratory even for an individual who had never been near an aeroplane.

Enthusiasm for psychological and psychotechnical methods was so general at the time that when Nechaev's article was printed in the Journal of Psychology, Neurology and Psychiatry there were no objections from specialists despite the confused nature of the conclusions.

It is true that individuals who were sceptical of such primitive methods began to appear amongst aviation doctors at this time. Thus for example Bogdanov published an article on Nechaev's work in 1923 in which he described the whole set-up of Nechaev's experiments and all his conclusions as "a husk which has merely to be discarded". But although he opposed the conclusions Bogdanov was himself attracted to psychotechnics and did not reach the level of rejecting the research method but was himself an ardent advocate of Münsterberg's method (Bogdanov, 1923).

Nevertheless the psychotechnical method which had been introduced into the Soviet Union from capitalist countries was openly a class method and deeply

fallacious. Its main drawback was its use of a method of test allegedly to measure and objectively establish differences in psychic aptitudes. In fact the results of the tests reflected differences in the social status, level of education and upbringing of those tested, differences in their material condition and so on. In searching for purely numerical criteria on which to base "diagnoses" and "forecasts" psychotechnics began to make a fetish out of the statistical method and showed excessive leanings towards measurement techniques in the use of mass psychotechnical tests. This gave rise to a completely untrue representation of the essence of the human personality, to a distorted view of the laws of its formation and development, to a deeply erroneous treatment of the problem of giftedness and capabilities and to a crude biological view of personality.

Therefore, in the initial stages of its development Soviet aviation medicine adopted an incorrect approach in attempting to solve the difficult questions of selection. In adopting the tests current in bourgeois psychology without any criticism and in relying on purely arithmetical calculations of errors and mistakes by the person being tested, Soviet aviation medicine fell into a psychotechnical approach from which it did not escape until the late 1920's.

ESSAY V

EMERGENCE OF SOVIET AVIATION MEDICINE

Although Mints was profoundly incorrect in his views on the need to use psychotechnical methods in the selection of pilots, his basic idea that it was essential to improve selection methods and to make a more profound approach to labor rationalization, to the systematic study of crashes and injuries and to the introduction of more thorough observation of the health of pilots had two positive effects.

On the one hand it was under the influence of this idea that psychophysiological laboratories (they were in essence psychotechnical) were set up in all flying schools (with few exceptions) in 1924. On the other hand the Main Administration of the Air Fleet set up a Central Psychophysiological Laboratory by agreement with the Military Medical Board and constructed a special building for the laboratory on the aerodrome.

These two measures immediately defined the main trend of Soviet aviation medicine, a trend that came to be known as the psychophysiological trend for its combination of the psychological and physiological methods.

Although the psychological methods meant in practice psychotechnics and the physiological methods were confined solely to the medical selection of pilots the term "psychophysiology" was universally accepted at the time.

In aviation it was a title that was further justified by the fact that by 1924 high altitude flight was becoming a pressing question for Soviet aircraft and there was therefore a growing need for true aviation physiology quite apart from the physiological aspects of selection. On the 19th of September 1924 M.N. Shalimo made the first Soviet ascent to an altitude of 8216 m and on the 6th of October Skrobut reached 8554 m.

Aviation doctors were not involved in either of these flights, oxygen equipment was not used and no detailed descriptions appeared in print; nevertheless, both these flights immediately brought Soviet aviation doctors face to face with the problem of high altitude physiology. From this time forward Soviet doctors paid attention, at first timidly and uncertainly but gradually more and more intently, to the physiological aspects of the effect of reduced atmospheric pressure. It was as a result of this that the physiological trend had developed in Soviet aviation medicine by 1925.

At the same time hygienic tendencies began to appear in Soviet aviation medicine in 1924 prompted, as was the general development of concepts in aviation medicine, by a series of long-distance flights undertaken by Soviet pilots.

In the summer of 1925 6 Soviet aircraft piloted by M.M. Gromov, M.A. Volkovoinov, A.N. Ekatov, I.K. Polyakov, N.N. Naidenov and A.I. Tomashevskii flew the 6500 km from Moscow to Pekin.

This flight provided brilliant proof of the development and achievement of Soviet aviation. Thanks to the production successes of the Soviet people headed by the Bolshevik Party the Soviet air fleet grew stronger and larger from year to year. By the time of the Third Congress of Soviets in 1925 Frunze could already note that the country was free of foreign dependence in aircraft construction. In the 6 years from 1920 to 1926 the Soviet Union had increased its number of aircraft four times over.

The justness of these words can be demonstrated by a number of facts from the history of Soviet aviation.

As early as 1925 the designer A.N. Tupolev had produced the ANT-3, the TB-1 (ANT-4) and the I-2. The K-2 was produced in 1926, the ROM-2 and the K-3 ambulance plane in 1927 and in 1928 Polikarpov produced the I-3 fighter with a speed of 300 kilometers an hour. Polikarpov, who also designed other types of aircraft including the R-5 and the PO-2, continued to work intensively on new fighters while Tupolev worked on new heavy aircraft. As a result Soviet aviation received a series of Soviet produced aircraft of high speed and great load-lifting capacity during the first five year plan. These aircraft included the R-5, the PO-2 (U-2), the I-3, the MU-2, the ANT-9, the Sh-1, the Sh-2, the Ya-3, the I-4, the TB-3 (ANT-6) and the Kaskr-1 autogyro.

The equipped Soviet aviators were enabled to achieve a number of outstanding successes.

In June 1926 Snegirev flew from Moscow through Sevastopol, Rostov, Lipetsk, Smolensk, Kiev and Vitebsk to Leningrad covering the 6500 km in 56 flying hours.

Also in June 1926 Kopylov flew the 2450 km from Moscow to Omsk in 20 hr 15 min.

In July 1926 Moiseev flew the 6200 km from Moscow to Teheran and back in an R-1.

In July 1926 Shebanov flew non-stop in a PM-1 from Moscow to Königsberg covering the 1180 km in 7 hr 45 min.

Also in July 1926 Mezheraup flew from Moscow to Ankara and for 290 km of the journey his land aeroplane was over the Black Sea.

In August 1926 Kopylov flew the 1650 km from Omsk to Kazan' nonstop in 12 hr 8 min.

In September 1926 Arvatov flew over the Hindu Kush, covering the distance of 1200 km in 9 hr 5 min most of which was spent at an altitude of 5550 m without oxygen.

Also in September 1926 Gromov made a notable European round trip in the Soviet ANT-3 taking in Moscow, Berlin, Paris, Rome, Vienna, Warsaw and returning to Moscow after covering 7150 km in 3 days (flying time 34 hr 15 min).

In 1927 Shestakov flew from Moscow to Tokio and back in a TsAGI-3, covering the 22 000 km in 153 flying hours.

In June 1928 Pisarenko flew nonstop from Moscow to Sevastopol in 6 hr 5 min at an average speed of 212 kilometers an hour.

In the summer of 1929 Gromov made a round trip from Moscow calling at Berlin, Paris, Rome, Marseilles, London, Warsaw and returning to Moscow in an ANT-9 ("Wings of the Soviets") covering the 9037 km in 53 flying hours.

In the autumn of 1929 Shestakov and Bolotov flew a TB-1 from Moscow to New York across Siberia and the Pacific, covering 21 242 km, for 8000 of which the aircraft was over water, in 142 flying hours.

These flights faced aviation doctors with a number of pressing problems concerned with fatigue of aircrews, their working and resting conditions, feeding, protection from the cold and other aspects. The flights also showed the need to devise ways of preventing the entry of exhaust gases into the pilot's cabin, improving flying goggles and antiphones and producing individual survival equipment for pilots flying over the sea.

Aviation doctors were faced with all these problems quite unexpectedly and had no experience in their solution. The small amount of material that had been translated and published in Vestnik vozdushnogo flota could in no way satisfy Soviet aviation doctors. Above all the earlier enthusiasm for psychotechnics had quite unfitted Soviet aviation doctors for the study and solution of problems in hygiene. The "psychophysiological" trend developed at the Central Psychophysiological Laboratory also contributed nothing to the solution of these problems. As a result, the clearly recognized need to develop work on hygiene as well as on psychological and physiological aspects remained a "pious wish" that was not implemented for a number of years.

CENTRAL PSYCHOPHYSIOLOGICAL LABORATORY FOR THE STUDY OF THE MILITARY AIR SERVICE

The Central Psychophysiological Laboratory for the Study of the Military Air Service developed a wide range of activities representative of the main trends in Soviet aviation medicine. Psychophysiology was represented by N.M. Dobrotvorskii, an assistant of the psychiatric clinic and by Yu.A. Vasil'ev, a research worker of Pavlov's school; the physiological trend was represented by A.V. Lebedinskii and the clinical trend by P.I. Egorov, N.A. Vyshnevskii and G.I. Kulikovskii. The laboratory also included an engineer (Gamburger) and a pilot (Fedorov), since the Main Administration of the Air Fleet made a special aircraft available for research. Strange as it may seem, no place was found for Mints in the laboratory although after his death it was named after him.

In 1924 therefore Soviet aviation medicine was solidly organized with a large central research establishment, a network of local psychophysiological laboratories and considerable numbers of medical officers attached to flying units. Initially the tasks assigned to the laboratories by the Military Medical Board were extremely modest: 1) to organize the selection of aircrew, 2) to organize health checks for aircrew and 3) to promote improvements in the living and working conditions of aviators. At this stage the laboratories were not given any research tasks.

By 1925, however, the Central Laboratory was so strengthened that it decided to extend the terms of reference that it had received from the Military Medical Board. Articles by Dobrotvorskii and Vasil'ev which were in the nature of programs appeared in the military-medical and aviation press. In their attempts to define the working methods of the laboratory its directors strove in particular to rid themselves of all of the psychotechnical preoccupations of Mints. "These methods were marred" stated Dobrotvorskii "by excessive subjectivism and every type of psychological and reflexological element". The only method to be permitted in the laboratory "should be Pavlov's objective method". Dobrotvorskii also asserted that "All the techniques and skills that the individual has to acquire in order to become a pilot are nothing other than conditioned reflexes". In accordance with this general orientation the laboratory was given the task of studying the functions of various analyzers under flight conditions. Some difficulties arose when discussing research method but the laboratory was confident that it could handle the task.

Vasil'ev gave a slightly closer definition of the problems facing the laboratory. He thought that in addition to determining reaction time, the accuracy of differentiation, inhibition and induction, the laboratory should also study emotional factors, the autonomic nervous system, fatigue, rational organization of the pilot's day, the role of the personal factor in air crashes and, lastly, the effect of air crashes on the "neuropsychic apparatus of the pilot".

Less than half a year later Dobrotvorskii was already in a position to print

Some Results of Work on the Psychophysiology of Flying (1926a) in which he asserted that "colleagues at the laboratory have already broken down all the operations performed by the pilot into their component parts", have established the time taken for each operation, and calculated the reaction time of the visual, auditory and muscular and articular analysors. It was true that some confusion was produced when a pilot received stimulation of several analysors at the same time and under these conditions "was dazed", but the workers at the laboratory hoped to solve this complication by first establishing the "inhibition" of the pilot.

Therefore, in Dobrotvorskii's words, the laboratory had undertaken the solution of three problems: "Firstly to study the state and functioning of the analysors needed by the pilot, secondly to study the functioning of the link between the analysors and the motor apparatus and thirdly to study the state and functioning of the motor apparatus itself".

The conclusion drawn from all this research was: "A pilot needs the function of the visual, muscular and articular, auditory and cutaneous analysors, precise differentiation of the stimuli reaching these analysors and precise agreement of the motor reactions in response to these stimuli" (Dobrotvorskii, 1925b).

In his annual report on the work of the laboratory Dobrotvorskii dealt in detail with the studies of fatigue in pilots carried out by Lebedev, Antonov, Kutakov, Lastochkin and Nil'skii. This research established a direct relationship between fatigability and the duration of flight and the number of landings carried out. Dobrotvorskii paid particular attention to Egorov's study of the functions of the cardiovascular system in pilots (1925) in which three types of functional adaptability of the cardiovascular system had been established.

The laboratory also studied changes in the accommodation of the eye under the influence of flights (Sergeev), the effect of unsuitable clothing on working capacity (Smirnov), the role of the personal factor in causing air crashes (Rozenberg), rationalization of the workplace of the pilot in the aircraft (Pereskokov) and other subjects.

Later research tasks of the laboratory included the study of metabolism in the performance of various flying operations, study of the functions of the hematopoietic organs during a flight and investigation of "electric processes in the organism".

It should be particularly stressed that from the very beginning of his activity Dobrotvorskii set himself the very involved and responsible task of creating a national system of aviation medicine based entirely on Pavlov's theory of higher nervous activity. He criticized the methods of foreign psychologists and psychophysiologists, which he thought were naive, crude and inadequately developed. He showed dissatisfaction with the Soviet investigators who blindly accepted the views of foreign authors and he thought that the introduction of research patterns and principles used in Europe or America was a profound mistake.

All these facts show that the Central Laboratory had taken on itself the heavy and involved task of defending Soviet aviation medicine against incorrect foreign theories and of directing it along what seemed to be the only correct, theoretically grounded and methodologically evolved path — the path of Pavlovian physiology. This reversal undoubtedly showed signs of revolutionary boldness since Pavlovian physiology was not widely supported by the medical profession at the time. The task was tackled by a small but tightly knit group of young and resourceful enthusiasts supported by the Air Force Staff and by the Military Medical Administration.

The scientific output of the laboratory was extremely large. Five publications were issued in 1925, eight in 1926, five in 1927, seven in 1929 and so on. The majority of these works were written by Dobrotvorskii and Egorov.

The main subject matter of Dobrotvorskii's work in the first three years was exclusively psychophysiological. There is now no need to examine each work in detail; suffice it to state that, inter alia, he worked on the methods of flying training, analysed the psychophysiological features of flying, examined questions concerned with the selection of fighter pilots and observers, provided a basis for the psychophysiological requirements that aircrew should satisfy and analysed the work of a pilot in a low-level flight.

As he became more and more deeply immersed in aviation Dobrotvorskii considerably extended the circle of his interests. More and more his attention was drawn to purely hygienic questions. He began to be interested in physical culture for pilots, working standards, feeding conditions, the hazards of the profession, the detection of these hazards in the work of technical personnel and other matters (Dobrotvorskii, 1926, 1929a, 1929c, 1930b etc.).

Dobrotvorskii's interest in these questions can be linked in time with his long round flight in the summer of 1927 from Moscow to Borisoglebsk, Kharkov, Kiev and back to Moscow. The flight was undertaken with the sole object of making a detailed study of the performance of the pilot and observer and in the course of the flight Dobrotvorskii carried out a vast number of physiological tests both on himself and on the pilot.

This was the first flight in the history of Soviet or world aviation medicine to be carried out by a doctor with the object of making a profound study of the work of the pilot under actual flight conditions. Unfortunately Dobrotvorskii's results were not published but it is known that his observations gave rise to prolonged discussion in the air force.

Dobrotvorskii's extensive knowledge of aviation obtained as a result of a great many flights, profound theoretical preparation and an excellent knowledge of the main problems in aviation medicine enabled him to produce the first Soviet text book on aviation medicine which appeared in 1930 under the title Flying. This book consisted of the lecture course delivered by Dobrotvorskii at the Zhukovskii Military Air Academy.

In the introduction Dobrotvorskii stated that the book contained "not so much an exposition of the physiology and hygiene of flight"... "as a step by step account of the nature of the effects on the organism of flying personnel under various conditions of the use of aviation". The book consisted of five chapters: 1) The tools of military flying, 2) The conditions in which air weapons are employed, 3) The operations carried out by pilots, 4) The operations carried out by observers and 5) The work of the aviation doctor and the organization of aviation medicine.

The reader is struck by the unusual structure of the book. It in no way reflects the achievements of aviation medicine either in the USSR or abroad but at the same time it does reflect the vast individual achievement of the author in the most varied branches of aviation medicine.

In the first chapter Dobrotvorskii gave some extremely important and valuable data on the size of the cockpit for pilot and observer and pointed out that the cockpit should be appropriate to the size of the aviator and mentions the most rational design of seating, pedals and control levers, instrument panels and so on. In dealing with these questions Dobrotvorskii consistently stressed the need to adapt the cabin and its equipment to the physical capabilities of the aviator.

The second chapter dealt with the effect of engine noise, exhaust gases, wind, reduced barometric pressure, oxygen deficiency, reduction in air temperature and the effect of the forces of inertia. The effect of acceleration was dealt with in particular detail. It should be noted that the effect of acceleration was a completely new question at the time. It is normally accepted in non-Russian literature that the physiology of acceleration was first raised by the Diringshofen brothers. Soviet aviation medicine can be proud of the fact that the priority in this question belongs to Dobrotvorskii, since his book appeared in 1930 whereas the first work of the Diringshofen brothers appeared in 1932. Dobrotvorskii gave a number of figures for the size of the excess load imposed by rectilinear and radial acceleration, pointed out that centrifugal force might possibly produce movement of the blood, that the weight of the internal organs was increased and that their displacement became possible, that disturbances of co-ordination developed during the action of acceleration and, in general, created the first correct view of the way in which acceleration acted.

The third and fourth chapters were devoted to the operations performed by fighter pilots, scouts, bomber pilots and observers. All these questions were analysed with extreme thoroughness and detail, in a way that revelaed the author's excellent knowledge of the work of aviators under various conditions, his deep interest in aviation, immense personal experience and wide knowledge of the literature. Questions concerned with the work and relaxation of air crew were dealt with for the first time in the history of aviation medicine.

The last chapter dealt with the work of aviation doctors, outlining their tasks and putting forward the first organizational plan. All of the points that Dobrotvorskii put forward in this chapter were so carefully thought out that they

remain true down to the present.

Despite the great energy that Dobrotvorskii had shown in studying the working conditions of aviators, despite the fact that he became a qualified observer in 1927 and received a number of money prizes and valuable gifts, the situation that developed in the laboratory was such that he was obliged to leave it in 1928. The official reason for his departure was discharge from the Red Army for reasons of health. But although Dobrotvorskii had left the laboratory he was unable to break with aviation. Initially he got himself a job as a supernumerary instructor in aviation medicine at the Zhukovskii Military Air Academy where he was a grade 1 instructor pilot-observer in the aircraft laboratory. From 1930 he was a staff lecturer in aviation medicine. During these years Dobrotvorskii published two works both dealing exclusively with questions of hygiene, one on flying clothing (Dobrotvorskii and Shur, 1931)and the other on the organization of flying duties (1931).

In 1935 Dobrotvorskii was once again able to return to his speciality. He was appointed as assistant to the Director of the Sixth Department in the newly organized Institute of Aviation Medicine. In this capacity his creative capacity was rekindled. Within two years he produced six interesting works all of which, like the preceding works, were devoted to hygiene. He dealt with the construction and equipment of working positions in aircraft, the hygiene of working positions, the special features of aerial marksmanship, ground training of bomb aimers, comfort in aircraft as a means of improving fighting capacity and measures for the control of overwork (Dobrotvorskii, 1936a, 1936b etc.).

Something was missing however. Dobrotvorskii could no longer adapt himself to his situation and find the necessary application for himself in the Institute and he was obliged to quit it in December 1936. When his last works appeared he was already a health officer in an outlying district of the Moscow region.

Nevertheless no failures and no setbacks could stifle this man's love for flying and devotion to it or extinguish the flame of his enthusiasm. He continued to believe that he still had something to contribute and that flying could make use of his knowledge and vast experience. He continued to believe that he could be of service to young aviation doctors. Therefore at the very beginning of the Great Patriotic War Dobrotvorskii volunteered for active service like a true patriot and became a staff doctor with the air force. Failing health forced him to retire at the end of the war. In retirement his health deteriorated still further and in 1947 he died at the age of 54.

The creative path of Dobrotvorskii, one of the first Soviet aviation doctors, was extremely interesting especially because of the evolution in his views over many years of intimate association with flying. Having initially formulated the need to transform the principles governing the selection and training of pilots on the basis of the Pavlovian theory of higher nervous activity Dobrotvorskii in practice followed the well-trodden path of experimental psychology and, being unable to reconcile these two trends, turned to problems of hygiene. Dobrot-

vorskii's life was also remarkable because he reflected the whole course of Soviet aviation medicine which started with pyrotechnics and moved gradually to the basic questions of physiology and hygiene.

Egorov was the other leading figure in the Central Psychophysiological Laboratory. He successfully combined the capacities of a clinical practitioner and a physiologist and during his work in the laboratory published approximately ten papers, some of which dealt mainly with the functional capacity of the cardiovascular system and others of which dealt with physiological aspects of high altitude flight. This duality did not hinder Egorov's work but, on the contrary, stimulated it. His knowledge of clinical medicine brought his physiological work closer to practical requirements and his competence in physiology contributed to his clinical work.

From the time that Egorov succeeded in constructing a Henderson-Pierce rebreather in the laboratory in 1927 he devoted himself entirely to the study of oxygen deficiency. After a number of years work with this apparatus slightly modified by Apollonov and Gamburger, Egorov formulated his material jointly with Pereskokov in a study entitled The Aviator's Altitude Ceiling (1931).

Egorov established from 69 experiments with pilots that on average an experiment with the rebreather had to be discontinued after 27-28 minutes when oxygen content in the apparatus had fallen to 7.96%, corresponding to an altitude of 7000 m. Pulse rate increased by 38%, respiration by 10.4%, the intensity of respiratory movements by 31.4% and maximum blood pressure by 12.4% while minimum blood pressure had fallen by 8.7%.

Egorov then first suggested the addition of carbon dioxide to the air breathed at high altitude. He established that the addition of 5-7% of carbon dioxide greatly improved the subjective and objective condition of the individual and also increased the ability to withstand altitude. Thus, whereas the maximum altitude was 6750 m when the air contained 0.01% of carbon dioxide it was 7250 m on average when carbon dioxide content was between 1 and 3% and 8000 m when carbon dioxide content was 3% and above.

These works laid the foundations for Egorov's subsequent extensive studies of the physiology of high altitude flight, which will be dealt with later on in the book.

The remaining scientific staff of the laboratory were far less active in a creative sense. Vishnevskii (1927, 1929) published only two works on the aiming capacity of the eye and on protective goggles. Lebedinskii published one work on the analysor of position (1927) and Vasil'ev rendered important service in translating the first American text book of aviation medicine by Bauer (1927).

The laboratory made a particularly valuable contribution by its extensive work on the compilation of regulations for the medical examination of pilots. These regulations were initially incorporated in order No. 322 of the USSR Revolutionary Military Council (1926) but the provisions of the order were re-

examined in 1928 and brought up-to-date by order No. 49 of the USSR Revolutionary Military Council which contained new provisions and physical standards and incorporated the first differential approach to different types of occupation in aviation. In 1929 the Military Medical Board of the Red Army issued a separate pamphlet produced by the scientific staff of the laboratory containing a detailed analysis of the procedure for examining pilots, the application of the clauses in order No. 49 and the method of compiling health records and statistics (Medical Examination, 1929). The main provisions of these instructions for the work of air force medical boards, the first such instructions since 1911, remained in force with slight modifications until the Second World War.

It is somewhat surprising that instructions devoted solely to clinical selection should speak continually of psychophysiological selection. The absence of any indication of the method of psychological selection was not due to the fact that these methods had been discarded but because the laboratory was not in a position at the time to establish the most suitable methods of psychological selection. Many doctors saw in the absence of any mention of the need for psychological selection an indication that psychotechnics had been rejected and began to concentrate attention solely on medical selection. However psychotechnics continued to be employed in selection in the majority of flying schools and in some schools, the theoretical school for example, greater importance was attached to it than to medical selection. It was not until 1931 that the Military Medical Board of the Red Army approved instructions for the carrying out of psychophysiological tests in air force schools worked out by the scientific staff of the laboratory.

In essence the psychophysiology in these instructions was pure psychotechnics. The whole testing program consisted of a series of tests augmented (for pilots) by a few apparatus tests including tests of visual estimation of depth, the motor system and negative induction.

The training courses for doctors organized by the laboratory were also of great significance in the history of aviation medicine. The first such courses were organized in 1926 and the first students included Zil'berman, Kutakov, Latkin, Lingart, Nil'skii, Rozenberg, Sergeev and Chaklin. The instructors were members of the scientific staff of the laboratory, employees of the Military Medical Board and some professors from Moscow.

Any assessment of the work of the laboratory should acknowledge that the period was one in which Soviet aviation medicine emerged. After its initial preoccupation with psychotechnics and a subsequent stage of enthusiasm for psychophysiology the laboratory embarked in 1930 on the correct path of physiological, clinical and hygienic study of flying conditions. One of the laboratory's great achievements was the carrying out of the first experimental studies of pilots during a flight, in the course of which Dobrotvorskii and Egorov carried out a number of flights of interest from the point of view of research.

The period should also be described as one of the emergence of Soviet aviation medicine because it was at this time that voices were raised in the lab-

oratory calling for rejection of the principles of foreign psychotechnics, rejection of the tendency to defer to bourgeois investigators, rejection of the uncritical acceptance of the attitudes of bourgeois science. It was a period at which the need was realized to create indigenous research methods permeated with Marxist-Leninist dielectics and based on the principles of Pavlovian physiology.

The laboratory did not succeed in carrying out all its projects, plans and tasks. In particular it did not succeed in freeing itself entirely of the psychotechnical approach, which was at the time firmly established in all research institutions concerned with labor rationalization. Nor did the laboratory succeed in avoiding a marked tendency towards a mechanistic approach revealed in attempts to compare pilots to machines and to reduce the involved and diverse operations of the pilot to simple muscular acts. Finally, the attaching of too much significance to the biological factor was a major fault in the work of the laboratory. This explains why, despite the sincere attempt of the laboratory to solve practical problems of flying training, there was much in its work that was abstract and that emphasized the gap between its work and the needs of the air fleet.

The laboratory failed to make allowance for the specific features of Soviet educational theory, which adopted the Marxist-Leninist outlook that education is subordinate to the laws of social development rather than to biological laws. Man does not merely adapt himself to his environment but actively transforms it. His behavior is conscious as well as instinctive, his activity is subordinated to consciously adopted aims and his habits are an intricate combination of consolidated conditioned reflexes.

Dobrotvorskii's departure from the laboratory in 1928 was a direct consequence of these mistakes. He was replaced as Head of the Laboratory by M.V. Raevskii, a man with no particular qualifications for an appointment in aviation medicine. In the two years that followed Raevskii failed to introduce any changes into the work of the laboratory, the nature of which ramained the same after Dobrotvorskii's departure as before.

THE WORK OF DOCTORS WITH OUTLYING UNITS

The articles of Mints and the considerable interest shown by responsible air force officers in the rationalization of methods for the selection of pilots and in the struggle to reduce crashes and injuries were the driving force behind the activity of doctors serving with outlying units.

The years 1925 and 1926 were ones in which there was a revival of aviation medicine in outlying units. It was a curious feature of this work that practically every local doctor attempted to follow a completely independent path in his

work. For some reason the approach outlined in Dobrotvorskii's program articles failed to attract the majority of aviation doctors and most of them were, without realizing it, sceptical of the achievements of the Central Psychophysiological Laboratory. The result of this was that few doctors followed the approach of psychotechnics and psychophysiology.

One of those who did was S.P. Rozenberg. Working in Odessa he succeeded in setting up a scientific section of the Odessa Flying and Aeronautical Society. In 1925 this section began to circulate a questionnaire containing 120 questions on the work and life of pilots. The results obtained were not published but it seems likely that the questionnaire was in fact Lippman's questionnaire used by Mints.

Rozenberg continued with psychophysiological work for the next 10 years. In 1928 he published an interesting and factual paper Standardization of the Instrument Panel of Training Aircraft in which he first pointed out the need for correct positioning of the controls of the aircraft. In an article on the work of aviation doctors published in 1929 he outlined the organizational tasks of an aviation doctor and his work in treatment and prevention. In 1930 he attempted to apply psychophysiological methods to the teaching of compass work and map reading. In 1934 in conjunction with Turov he constructed a special apparatus to study the coordination of the pilots' movements and gave some results of work with this apparatus. In 1936 he worked in collaboration with Vengrzhenovskii on the importance of convergence in selection for flying schools. Finally, in 1938 he collaborated with Barinshtein and Babskii in producing a most detailed list of indications and contraindications for the transport of sick and wounded in aircraft (Rozenberg, 1938).

Rozenberg's work shows him to have been an enthusiast. He made a thorough theoretical and practical study of flying, which he attempted to rationalize by psychophysiological methods, but the absence of a school made it difficult for him to extend his work and gave rise to natural fluctuations in subject matter.

Bogoyavlenskii developed in a quite different direction. His first work (1924) on variations in pulse rate in pilots during a flight and his second work (1925) on the organization of first-aid services in naval air units were published when he was senior physician of the School of Marine Aviation. Both articles were well written and revealed their author as a man with an excellent knowledge of the naval air service. In his articles Bogoyavlenskii put forward a number of carefully thought out and mature comments on inadequacies in the medical care provided in naval air units, the unsuitability of the flying clothing issued to pilots in the naval air service, the unsatisfactory nature of life saving equipment, the importance of safety belts and so on. These were all questions of importance in the naval air service, questions which showed that Bogoyavlenskii was responsive to the needs of his unit and that he understood clearly that the future of aviation medicine must be concerned primarily with the provision of the correct medical and health services.

Bogoyavlenskii's subsequent work was somewhat held back since he did not publish anything for the next three years. It was not until 1928 that he published a small article on air ambulances, and after this he disappeared from the literary horizon.

Nil'skii worked for a number of years at the theoretical school on the functional activity of the cardiovascular system in all those who entered the flying school and in all pilots who were examined. The extensive material that he accumulated was incorporated in his article The School and Achievements of a Physiological Order published in 1928.

These three examples show the distinctive nature of the development of Soviet aviation medicine, which was also a feature of the years that followed. From time to time the name of some aviation doctor who had written a few interesting articles, always on a vital and urgent subject, would appear in Vestnik vozdushnogo flota and then be lost from view (all Soviet aviation doctors owe a debt of gratitude to this journal and to its editor A.N. Lapchinskii).

At the same time it was only the psychophysiological trend (in practice the psychotechnical trend) in outlying psychophysiological laboratories that was actively supported by the Central Laboratory and the Military Medical Board (mainly by Zalkind), but these laboratories did not have any scientific output.

By contrast the work of Pereskokov, the senior physician of the Zhukovskii Military Air Academy, followed a new and distinctive approach. Despite physical proximity and close connections with the Central Laboratory Pereskokov followed his own line in scientific work. His very first work, which was an analysis of the situation of the pilot in the aircraft from the point of view of labor physiology (Pereskokov, 1926a), attracted attention for the novelty of the question raised. In the same year Pereskokov dealt with two questions: 1) the forms of sport that pilots should take up and 2) the role of the doctor in organizing the living conditions of aircrew.

However Pereskokov found his true vocation when he turned his attention to the study of oxygen apparatus. By 1931 his extensive work on oxygen apparatus had been incorporated in The Aviator's Ceiling and from this time onwards he was an acknowledged specialist on the subject.

The work of these four doctors did not, of course, exhaust the work of doctors in outlying units. In fact such doctors did much more but their research was normally carried out for the Central Laboratory and their information obtained in the course of practical work was widely used by the laboratory. Unfortunately this work was not published and special research would therefore be needed to estimate its significance in the history of aviation medicine.

In conclusion it can be stated that this period in the history of Soviet aviation medicine was one of emergence, since its main distinguishing feature was the gradual freeing of aviation medicine from foreign influences, the formulation of its own theoretical principles, the wide development of research work both in the newly organized Central Psychophysiological Laboratory and in outlying units and the selection of qualified doctors for aviation medicine.

The following trends emerged clearly in Soviet aviation medicine during the period: 1) a psychophysiological trend, replacing the former psychotechnical trend, but with little essential difference; 2) a physiological trend confined to the study of the effect of altitude and 3) a clinical trend that led to a well thought out system of medical selection for pilots. The hygienic trend had not yet developed but the need for it was already apparent. This need was not met by The Hygiene of Flight by Latkin and Yakovlev which appeared in 1931.

The beginnings of a special course in aviation medicine, including aspects of physiology and labor hygiene, began to be formulated in the USSR during this period. In a word it was a period of persistent search for an independent approach, a period of heated disputes, enthusiasms and disillusionments, a period of gradual liberation from the tenets of psychotechnics, a period in which theoretical errors were overcome and Soviet aviation medicine became conscious of its strength and potentialities.

ESSAY VI

AVIATION MEDICINE OUTSIDE RUSSIA 1920-1930

If the history of aviation medicine is considered in relation to the development of aviation the 1920's must be divided into two periods: 1920-1925 and 1925-1930. This division is necessitated by the uneven development of aviation and the aircraft industry outside Russia during these periods, the first being a period of stagnation and the second one of emergence from stagnation and revival of the aircraft industry.

At the end of the first World War the victor states found themselves in possession of vast resources in aviation for which it was difficult to find a use. As a result the production of aircraft and aircraft engines was reduced by more than 95% in the great majority of the victor countries. This led to prolonged stagnation in the development of aviation technology. The profound crisis of aviation and the stagnation were made particularly acute by the general economic crisis that developed after the war throughout the capitalist world.

It was not until approximately 1925 that the main capitalist countries began gradually to emerge from the economic crisis and it was at this time also that the aircraft industry began to revive.

The crisis that affected aviation and the aircraft industry between 1920 and 1925 was bound to have an effect on aviation medicine outside Russia in that period and to hold back medical research for a long time. This stagnation was even more prolonged than the stagnation in the aircraft industry and in essence covered the whole period between 1920 and 1930. It was only in the late 1920's that there was some emergence from stagnation and even this was not general.

The main factors responsible for the extremely slow development of aviation medicine outside Russia were a decline in public interest in flying, a great reduction in airforce personnel and stagnation in the development of aviation technology. Subsidiary factors included the demobilization of trained aviation doctors, organizational collapse of the airforce medical service in the majority of countries and the closing down of psychophysiological laboratories concerned with the selection of military aircrew.

As a result nothing new was achieved in European aviation medicine in the 1920's. There was not a single new idea or new trend, no new statements of

principle were developed and no new research techniques, apparatus or equipment were produced.

This state of stagnation is objectively reflected in the extreme scarcity of scientific publication at this period and in the proceedings of the medical sections of international congresses on aerial communications. All countries (apart from the USSR and the USA) were represented at these periodic congresses and the reports, discussion and resolutions of the plenary sessions are, of course, of interest for their bearing on the development of aviation medicine.

Five international congresses were held between 1920 and 1930. The first was convened in 1921 in Paris, the second in 1923 in London, the third in 1925 in Brussels, the fourth in 1927 in Rome and the fifth in 1930 at the Hague. The state of European aviation medicine during this period is revealed with exceptional clarity by a study of the materials of the medical sections of these congresses and an analysis of the papers and discussion and the resolutions adopted.

AVIATION MEDICINE IN EUROPE

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The first congress (1921) had no bearing on the history of aviation medicine since there was no medical section, it was not yet standard practice to issue general invitations to aviation doctors and the only representatives of aviation medicine were the French. Only four papers on medical aspects were delivered at this congress. Bein and Behague presented a paper on the practical value of psychomotor reactions based on wartime materials, Cruchet dealt with the old subject of aviators' disease, Ferry with the development of irritability in the course of flying training and Gourdon and Lessor with a new type of oxygen apparatus subsequently adopted by the French air force.

These four papers were passed over unnoticed. There was no discussion on them and the first congress did not adopt any resolutions on aviation medicine since the rapporteurs failed to put any clear proposals to the plenary session.

The second congress (1923) already included a separate medical commission under the chairmanship of Martin Flack. It cannot be considered that this commission was particularly productive since it received only four papers, three by French authors and one by a British author. Devalouet attempted to study the mechanism of wound injury in air crashes but failed to reach any conclusion apart from the generally accepted fact that the most frequent injuries were head injuries. Munro reiterated the basic principles underlying the medical selection of pilots and Garsaux gave a detailed report on the first temperature and pressure

chamber at Le Bourget and his own (extremely scanty) observations of work with it. A paper by Hill (United Kingdom) with the portentous title The Human Machine in Aviation was the main feature of the commission's work.

In discussing this paper those present came to quite unusual conclusions. For example, they agreed unanimously that: 1) a moderate amount of flying has no effect on the pilot's organism, 2) wear and tear on the organism is no greater in a pilot than in any other profession and 3) the health of pilots is that typical of their age group.

It is to the credit of the plenary session of the congress to which these conclusions were presented that some justifiable scepticism was shown towards such categorical conclusions and the only resolution adopted stated that although the medical commission had reached certain conclusions the "plenary session expressed the desire to see the results of accumulated observation on the physical condition of pilots employed in aviation for a long period".

The conclusions reached by the doctors at the second congress were the fruit of disillusion based on the fact that it had seemed to the first aviation doctors that flying would bring nothing to mankind except new diseases. They had wished to provide objective proof with the imperfect methods at their disposal of the inevitable premature wearing out of the organism. This is the only possible explanation for the widespread use in aviation medicine outside Russia between 1916 and 1920 of such terms as "aviators' disease", "aero-neuroses", "pilots' asthenia", "descent disease", "aviators' cardiac hypertrophy" and so on. The first aviation doctors were inclined to treat every temporary functional disorder as a permanent disability leading almost unavoidably to the invaliding of the pilot.

Naturally enough such conclusions were not confirmed by more prolonged observations: no persistent organic changes were discovered in pilots. Unable to discover any premature wearing out of the organism aviation doctors went to the other extreme and denied that, in general, flying had any effect on the pilots' organism. It was this that prompted the bold and unusual conclusions of the doctors at the second congress.

These incorrect negative conclusions born of disillusion could not however overthrow the principles and real basis of aviation medicine any more than mistakes in addition and subtraction could lead to the rejection of arithmetic. On the other hand they undoubtedly retarded the development of aviation medicine and increased the stagnation.

At the third congress (1925) the medical commission was extremely active and was attended by doctors from the United Kingdom, France, Belgium, Italy, Holland, Germany, Poland and Rumania. The number of papers presented (16) eclipsed the work of some of the other commissions at the congress. On the other hand the quality of most of the papers was fairly low.

The largest number of papers was presented by the French (10). Representatives of the United Kingdom and Poland each put forward two papers and representatives of Italy and Rumania one paper each. The overwhelming majority of the papers were, in essence, materials from before the war and they dealt in the main with the selection of pilots without proposing any new methods. This applied in particular to the extremely long paper by Hild (United Kingdom) which touched on almost all the main questions in aviation medicine but in which, in relation to selection, the rapporteur merely insisted on the extension of clinical methods which should be augmented by research on the coordination of movements with a Reade apparatus and the introduction of Tucker's apparatus to study acuity of hearing.

Flack (United Kingdom) thought that the functions most essential to a pilot were vision, neuromuscular coordination, muscular and articular sensation and the otoconia. He also supported the introduction of the Reade apparatus and study of the otoconia by the Bárány chair test. For the rest he insisted on the study of the time for which the breath could be held, pneumatometry and functional tests of the cardiovascular system.

Papers on the significance of psychophysiological studies were presented by Bein (France) and Braban (Belgium). Bein arrived at the conclusion that the speed of a simple psychic reaction was no criterion for the selection of pilots; better results were yielded by a reaction involving choice; equally good results were obtained by the study of kinesthetic memory. Nevertheless no single psychophysiological test was in itself sufficient to demonstrate the suitability or unsuitability of a pilot but a combination of such tests could be of value in selection. The only suggestion made by Braban was that two figure numbers should be used to test the pilot's attention.

Physiological questions were raised in the papers of Anastasiu (Rumania), Bein (France), Garsaux (France) and Cruchet (France).

Anastasiu presented a report on measurements of blood pressure before and after flight in 220 pilots and found that in the majority of cases blood pressure remained higher after the flight. Cruchet gave experimental data for changes in blood pressure during simulated ascent in a pressure chamber. He found that systolic pressure was always increased and that diastolic pressure was scarcely affected. Breathing oxygen restored blood pressure to normal. Bein gave his calculations of oxygen supply at different altitudes: his figures were 9.91 liters of oxygen per minute at 3000 m, 2.83 at 6000 m and 3.83 at 10,000 m. In his other paper Bein gave results of investigations of variability in the dark adaptation curve of the retina and recommended on the basis of his data that purple-red lighting should be employed in pilots' cabins. Garsaux demonstrated his new liquid oxygen apparatus.

The two papers by Ferry (France) were in a class by themselves. One of these papers on the perennial theme of "aviators' disease" differed from Ferry's previous communications on the subject in that he now distinguished

two stages of the disease. The first stage consisted of temporary cardiovascular reactions. The second stage was accompanied by albuminuria, adrenal insufficiency, depression, asthenia, atony of the gastro-intestinal tract and azotemia. All these terms were used generally and were unsupported by case histories, figures or objective data. Ferry's second paper had the portentous title The Causes of Crashes in Flights in Aircraft and Methods of Avoiding Crashes but in fact the rapporteur recounting a personal incident in which he had experienced complete disorientation during a steep spiral and had avoided a crash only by trusting his instruments. This paper gave rise to a lengthy discussion on whether a pilot should trust his sensations or his instruments.

There was also a distinctive communication from Rouleaux (Belgium) on the possible transfer of infectious diseases from country to country in aircraft. The rapporteur insisted on the need to extend the statutes of the international convention on rail freight to transport aircraft.

Ambulance planes were dealt with in papers by Angelo di Nola (Italy), Sand (France) and Tilman (France).

Arising from its discussion of all these papers the medical commission of the third congress put forward four demands: 1) the International Red Cross should declare the neutrality of ambulance aircraft in time of war, 2) all instruments and their positioning in the aircraft should be standardized as far as possible, 3) the position of instruments on the instrument panel and the side of the cabin should be such that the pilot's head should be protected from damage in the event of a crash, 4) pilots should place more reliance on instrument readings than on their own sensations during flight.

The medical commission of the fourth international congress on aerial communications (Rome, 1927) was represented almost entirely by the Italian contribution which accounted for eleven of the eighteen papers. Despite the extreme diversity of theme, however, the plenary session adopted only one resolution concerning the further development of ambulance aircraft. The congress decided to set up a special commission whose members should be representatives of all the member states to make a detailed study of the organization of the ambulance plane service in each country and to report on actual activity.

Examination of the work of the medical commission at the four international congresses and the resolutions adopted therefore provides a clear demonstration of the extreme stagnation of aviation medicine outside Russia during this period.

From approximately 1925 the world economic crisis gradually receded and there was a revival of interest in all countries. The contradictions that had not been resolved by the Versailles treaty led to the commencement of preparations for a new war in the capitalist countries. These preparations included extensive plans for the re-equipping of air forces envisaging the production of new models, extensive financing of scientific research, the creation of trained reserves of personnel and expansion of the aircraft industry. Aircraft production began to expand in Czechoslovakia, Poland, Holland, Sweden, Spain and other countries. The statistics show that more than 50,000 aircraft, of which more than 75% were military aircraft, were built in the capitalist countries between 1925 and 1929. As a result aviation technology moved very far ahead in the capitalist countries during this period and the airctaft industry became a leading branch of production.

In practice this took the form of the design of new faster aircraft capable of reaching high altitudes and with a longer effective range. By 1930 there had been considerable increases in the records for speed, altitude, distance and duration of flight.

The speed record, which had been 313 km an hour in 1920, had increased to 448 km/hr in 1926 and to 575 km/hr in 1929.

The altitude record, which was already 10,093 m in 1920, reached 11,700 m in 1927 and 13,100 m in 1930.

The distance flown without landing, which had been 3,200 km in 1921, had increased to 6,000 km by 1927.

The duration of flight without landing, which had been 24 hr 19 min in 1920, had increased to 51 hr 11 min 25 sec in 1927.

It is true that these were record achievements and that the majority of countries continued to use old slow aircraft with little weight-lifting capacity and not capable of reaching high altitudes. Nevertheless these records were indicative of the revival of the aircraft industry.

The development of aviation in this period was bound to stimulate the further development of aviation medicine, but the development was uneven in different countries. In some countries aviation medicine was developed and improved while in others it continued in a state of decline. A revival was noted in Germany, Belgium, Holland, Denmark, Poland, Japan, Hungary, Czechoslovakia, Rumania, Spain, Argentina and other countries, but aviation medicine failed to develop in the main capitalist countries (the United Kingdom, the United States and France).

These facets of the development of aviation medicine in different European countries were clearly revealed at the fifth international congress on aerial communications which opened at the Hague in 1930. The medical commission of this congress, under the chairmanship of Professor Beck had 32 papers on its agenda, 12 presented by the Italians, 10 by the French, 2 each from Belgium, Holland and Poland and one from Rumania, Hungary, Denmark and Czechoslovakia. The British delegates failed to present any papers.

The most important and interesting papers were the Italian and Dutch communications which reflected extremely profound examination of aviation medicine problems. The French communications were the least significant. The main French rapporteur was the indefatigable Ferry who presented six papers but his contributions were, as previously, marked by superficiality and hasty conclusions.

Of the 32 papers 8 were devoted to physiological, 13 to clinical, 3 to psychotechnical and 8 to general questions of aviation medicine. It was a feature of the work of the medical commission that the clinical and general questions provoked lively discussion whereas the papers on physiological themes failed to provoke any discussion although some of them were of great interest.

The most important on a physiological question was presented by Jongbloed (Holland) who gave an account of his observations of variation in the composition of alveolar air in simulated ascent in a pressure chamber to an altitude of 14,000 m and gave the following standards for oxygen supply at different altitudes: 3.4 liters per minute at 6,000 m, 4.6 at 9,000 m and 6 at 12,000 m. This paper contained the first description of the symptoms of decompression sickness and a correct interpretation in terms of its nitrogen etiology.

Other papers to attract attention included:

1) a communication by Talenti and Margaria (Italy) on changes in pulmonary ventilation, respiratory quotient and the composition of the alveolar air in ascents of up to 5000 m; the authors examined these changes in the light of Mosso's concept of acapnia;

2) a communication from Missyuro (Poland) on his experimental work on gas metabolism in three pilots flying at different altitudes; pulmonary ventilation was found to increase from an altitude of 3000 m, the amount of carbon dioxide exhaled increased to 5.43%, oxygen consumption rose and the respiratory quotient increased;

3) a paper by Schubert (Czechoslovakia) in which the rapporteur demonstrated that pulmonary phyperemia at high altitude was due solely to the mechanical effect of reduced barometric pressure;

4) a paper by Cacciapuotti (Italy) on the significance of the mechanical effect of low pressure in the pathogenesis of altitude sickness;

5) a second paper by Jongbloed (Holland) concerning physiological observations of four pilots who flew from Holland to Indonesia, covering a distance of 28,000 km in 40 days. The author failed to detect any signs of fatigue in the pilots and concluded that it would not be long before an eight hour working day was introduced for pilots;

6) a communication from Marulli (Italy) on reduction in the time for which the breath could be held at high altitude, and

7) a communication from Acqua (Italy) on the absence of any changes in blood sugar level during a flight at an altitude of up to 4,300 m.

Almost half the papers on clinical questions were devoted to the functions of the vestibular apparatus in pilots.

The main paper on this subject was presented by Quix (France), who in essence repeated the points that he had made in his book Sea Sickness and Aviators' Sickness published in 1924. Brouvert (Belgium) demonstrated that factors such as the ventilation system of the aircraft, the heating system, noise, vibration, inhalation of exhaust gases, visual stimuli and, finally, mental state played a part in the pathogenesis of air sickness. Ericson (Denmark) demonstrated a new instrument for determining balance functions. Camy (France) made a critical analysis of all methods for studying the vestibular apparatus. Casella (Italy) demonstrated that no changes were detected in the functions of the otolithic apparatus in simulated ascents in a pressure chamber.

Two papers by Pol (France) and Carrucchio (Italy) were devoted to the study of color perception in pilots; Anastasiu (Rumania) spoke on the need for careful treatment of malarial pilots; Ferry (France) insisted that pilots being treated for syphilis with arsphenamine should be suspended from duties for eight days; Scala (Italy) observed jaundice in a pilot who had made a parachute descent from 5000 m and considered that it was of emotional origin; Alliotti (Italy) observed changes in the urine after descent and suggested that there was a picture of true uremia in some cases and that this was the cause of some air crashes.

There was a particularly interesting communication from Ferrari-Lelli and Accorinti (Italy) on morphological changes in the lung tissue of rabbits killed at various altitudes. The microphotographs presented showed clear signs of alectasis and infarction of the lung tissue, marginal emphysema and hemorrhage.

The fact that only three papers were presented on psychotechnics showed that there had been a decline in interest in this method. This was demonstrated by Ferry's paper (France) in which it was directly stated that the study of psychomotor reactions had no significance for pilots and that in the selection of pilots stress should be shifted to clinical methods.

It is true that Acqua (Italy) made a further attempt to prove that the emotional state of a pilot could be best revealed by psychotechnical tests and Capek (Hungary) recommended that the method of psychogalvanic reflexes should be used to detect a latent complex, but these suggestions failed to meet with any support.

The most lively discussion centered around papers concerning general questions of aviation medicine. The three questions raised were nomenclature in aviation medicine, the aviation doctor and the employment of women in aviation.

Giacomelli (Italy) showed clearly in his paper that there was great confusion in such terms as "aviators' sickness", "altitude sickness", "air sickness", and "descent sickness". He suggested that four terms should be retained: 1) altitude sickness, 2) air sickness, 3) flying sickness or aeroneurosis and 4) acceleration sickness. Despite lengthy discussion no consensus of opinion was reached.

Of the four papers on the training and qualifications of aviation doctors one was presented by Brouvert (Belgium) and three by Ferry (France). The main question was not the theoretical and clinical training of an aviation doctor but his flying training, since both the rapporteurs and those who took part in the discussion insisted that every aviation doctor should be a pilot. Although the British delegates (Flack) were sceptical, this requirement was accepted by the majority. In arguing his case Ferry even insisted that doctors on the reserve earmarked for service with flying units should also receive flying training and that only doctors in possession of a pilot's certificate should be put in command of squadrons of ambulance planes. A Polish delegate brought some calm to the meeting by acknowledging the right of aviation medicine to a separate existence and calling for the setting up of an international association of aviation doctors, but he too finally agreed that aviation doctors should be pilots.

Garsaux (France) presented a patently reactionary paper on the employment of women in aviation in which he stated that women could not be pilots owing to their "biological inferiority". All discussion on this paper was killed by Flack's cold retort that there was a different view of women in Britain and by the extreme poverty of Garsaux' arguments in support of his ideas.

The final plenary session of the fifth congress adopted four resolutions arising from the work of the medical commission:

1. The congress expressed its desire that the Dutch government should address all states suggesting the creation of an international association of all doctors concerned with the study of flying. To this end the congress appointed a provisional committee for the association (Beck, Brouvert and Jongbloed). Doctor Sillever was asked to organize the production of a journal of aviation medicine.

2. The congress called for experimental studies of the most rational lighting of the pilot's cabin for night flights.

3. In view of the particular importance of combating air sickness the congress called on aircraft designers to improve the quality of ventilation and heating and on aviation doctors to continue experimental work on air sickness.

4. Conscious of the fact that aviation medicine was becoming a special branch of medical knowledge, the congress expressed a desire to see aviation doctors with better training both in physiology, pathology, therapy, psychoneurology and hygiene and in aviation technology, such training to include frequent flights. Although not laying down that aviation doctors should obtain a pilot's certificate, the congress expressed the opinion that frequent flights would enable doctors to gain a more complete idea of the demands made on the pilot's organism.

GENERAL DEVELOPMENT OF AVIATION MEDICINE IN THE MAIN EUROPEAN CAPITALIST COUNTRIES

In summing up the work of the medical commissions at the five international congresses it can be seen that they were definite turning points in the development of aviation medicine and that the successful wartime development in the main capitalist countries (the United Kingdom and France) had been followed by prolonged stagnation at the end of the war.

United Kingdom. The stagnation was particularly apparent in British aviation medicine. British delegates played a leading role at the first three congresses but not at the fourth and they failed to present a single paper to the fifth.

This situation was somewhat unusual since British aviation doctors were in possession of a wealth of material by 1930 on the physiology of high altitude flight. Suffice it to mention the interesting information obtained by Barcroft during his high mountain expeditions in 1910, 1911, 1912 and 1921 and during six days in 1919 spent with three colleagues in a pressure chamber in which the air contained 11% of oxygen, and Haldane's materials in his book Respiration* first published in 1921. The only possible explanations for neglect of these data are the conscious separation of aviation physiology from general physiology, already mentioned, or a conscious unwillingness to acquaint the representatives

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*J.S. Haldane and J.G. Priestley. Respiration. Oxford, 1921.

of other countries with the extent to which British aviation physiology was making use of the achievements of general physiology.

France. The role of France in the development of aviation medicine also declined sharply in the postwar period. It is true that Ferry continued to produce papers and struggled to revive the corpse of "aviators' sickness" but his statements no longer attracted attention. At the same time it cannot be stated that there was complete stagnation in aviation medicine in France between 1920 and 1930. Bein produced some work on various subjects, Bayeaux published interesting data on structural changes in lung tissue following time spent at high altitude, Quix published his detailed study of sea sickness and air sickness and, finally, in 1928 Behague, Garseaux and Richet made the first ascent in a pressure chamber to an altitude of 13,800 m*. Even so this was extremely little for a period of ten years.

Germany. Aviation medicine began to revive in Germany during the period. German representatives, who first attended the third congress, did not present a single paper to the third, fourth or fifth congresses. Koschel, the permanent German representative to all the congresses, fiercely attacked certain papers at the fifth congress but his contribution to the discussion was so coldly received that he made no further attempt to take part. Nevertheless the facts indicate that work on aviation medicine was being carried out in Germany in the 1920's. Thus, for example, oxygen equipment for pilots was being produced by the firm of Dreger from 1924 onwards. In 1927 Brauer set up the world's first institute of aviation medicine in Hamburg. The institute had a well-equipped altitude chamber. In the same year a course on human physiology in flight was added to the curriculum at Würzburg University. In 1929 the German pilot Neuenhofen set up an altitude record using Dreger's oxygen apparatus by ascending to 12,739 m. The works of Kaiser began to appear in German technical publications from 1928 onwards and those of Gillert and Strughold from 1929**. By 1930 German aviation medicine had developed to a point at which Brauer began to publish an international journal of aviation medicine (Acta aerophysiologica).

German research differed from British and French work of the period in that the centre of gravity was shifted to the physiology of high altitude flight, and the physiological trend adopted by German aviation medicine by the end of the 1920's subsequently became the main leading trend.

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*R. Bayeaux. Compt. rend. Acad. des Sci. Vol. 180, 1925; F.H. Quix. Le mal de mer. Le mal des aviateurs. Paris, 1924; Behague, Garsaux and Richet. Compt. rend. Acad. des Sci. Vol. 186, 1928.

**E. Gillert. ZFMH. No. 14-15, 1929; H. Strughold. ZFMH. No. 14-15, 1929.

The Himalayan expedition of 1931 with Hartmann as physiologist played an extremely important part in the development of German aviation medicine. Even so aviation medicine in Germany had not developed beyond a new and interesting but purely academic field of knowledge before 1933. It was only from 1933 when an air force and a ministry of aviation were finally set up in Germany that aviation medicine began to be of great practical significance. From this time onwards there was planned development of aviation medicine and it had an ever increasing effect on the work of the German air force. There is no doubt that the altitude record (1400 m) and the speed record (600 km/hr) set up in 1933 by German pilots were made possible by the achievements of aviation medicine.

Italy. The development of aviation medicine between 1920 and 1930 was particularly intense in Italy. In addition to the continuing work of Gemelli, such major physiologists as Herlitzka, Margaria, Talenti and Lomonaco turned to the study of aviation medicine. During the period the laboratories of Herlitzka and Margaria published a vast amount of research. One of the most important of these works was Herlitzka's Physiology in Aviation published in 1923. The main trend of the Italian school was also physiological and concerned with the physiology of high altitude flight. The dominant theme was justification of Mosso's theory of acapnia and support for the use of carbogen instead of pure oxygen at high altitude. This attitude was supported with particular strength by Herlitzka who recommended that a mixture of oxygen and 7% of carbon dioxide should be breathed at high altitude*. It was not until the late 1930's that, as a result of the prolonged work of Margaria, Talenti and Lomonaco, the Italian school gradually realized that the pathogenesis of altitude sickness could not be explained in terms of the theory of acapnia**.

Several major research centers were set up in Italy in 1933 to study aviation medicine. These centers were headed by Margaria, Talenti and Lomonaco.

In conclusion it should be emphasized that the physiological trend was the main trend in aviation medicine in the major European capitalist countries during the second half of the 1920's. It is, however, true that the majority of aviation physiologists continued to believe incorrectly that aviation physiology was separate from general physiology. They continued to reject the possibility of using materials yielded by high mountain expeditions or by experiments involving the breathing of gas mixtures with a reduced oxygen content. This is the only possible explanation for the lack of reference to Barcroft's theory of the respiratory function of the blood or to the research data of Haldane,

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*A. Herlitzka. Fisiologia de aviazone. Bologna, 1923.

**R. Margaria. Revista di med. aeronautica. Vol. 2, 1939; R. Margaria and C. Talenti. Acta. aerophys. Vol. 1 No. 1, 1933.

Henderson, Schneider and others whose works contributed largely to the theory of aviation medicine outside Russia.

There was no further development to the clinical trend between 1920 and 1930.

During this period the hygienic trend was revealed mainly at the first international congress on air safety held in Paris in 1930. The papers presented to this congress on purely hygienic subjects included a paper by Ball on protection of the hearing from noise, by Flamm on the safety aspect of uniforms, by Shelley-Beer and Perren de Brishambo on flying clothing, by Pravaz on the protection of pilots from cold, by Charlier on the hygiene of the oral cavity in pilots and by Faumbert on protection of the eyes*.

The psychotechnical trend died out slowly but surely. It was still supported by individuals in France, Italy, Poland and Hungary but it was clear that the hopes once placed on it as a rational method for the selection of pilots had gone, apparently forever.

AVIATION MEDICINE IN THE UNITED STATES

American aviation doctors found it necessary to go their own way and took no part in the work of the medical commissions at the congresses on aerial communications. Having made use during the war and in the immediate postwar years of all the achievements of European aviation medicine the Americans with their considerably greater technical resources began to develop their own trend on the other side of the Atlantic.

Organizationally this found its expression firstly in the setting up of the Air Service Medical Research Laboratory at Hazelhurst airport (Long Island). This laboratory, which was first opened in January 1918, closed by 1920 not because of any decline in interest in the problems of aviation medicine but because a more solid institution, the School for Flight Surgeons, already equipped with an altitude chamber had been opened in May 1919 at Mitchell Field. In December 1922 this school was renamed the School of Aviation Medicine. In October 1931 the school was moved to Randolph Field (Texas) where it has remained to this day.

Throughout this time the School for Flight Surgeons was the centre of all scientific research on aviation medicine in the United States. The main questions with which it was concerned in the 1920's were: 1) the physiology

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*I Congrès international de la sécurité aérienne. Vol. 2, Paris, 1930.

of high altitude flight, 2) the physiology of blind flying, 3) study of the reactions of the cardiovascular system to various types of stress under conditions of oxygen starvation, 4) the physiology of night flying, 5) study of character traits in the pilot's personality from the point of view of suitability for flying*.

The problem of overriding significance was that of the physiology of blind flying. American aviation doctors (especially Myers) had worked out the main principles of instrument flying as early as 1924 and had designed special cabins for ground training in blind flying. The Americans kept the results of their research in this field secret for twelve years and only published them in 1936.

In addition to Schneider's continued research, a great deal of work on the physiology of high altitude flight was carried out by Gilbert and Green. Like Schneider they were mainly concerned with the reactions of the cardiovascular system to anoxia. Their works published between 1920 and 1924 gave details of changes in pulse, blood pressure and electrocardiography in acute anoxia. Their information in essence augmented and confirmed Schneider's research results.

The most significant clinical research was concerned with the dark adaptation of the retina, which was a problem with direct bearing on the physiology of night flying. The physiology of the labyrinth was another question to attract the attention of clinical practitioners. However, despite the fact that a great deal of attention was paid to this question, the quality of the published research (Robertson, Dodge, Scott and others) was not very high and added nothing new for those acquainted with the standard work by Quix.

The psychologists were responsible for the least effective work. Psychological examination of pilots has been conducted in the United States from the very beginning of aviation medicine and is still carried out today but the published materials are so few and so poor in content that it is impossible to arrive at any opinion on the nature of the work carried out and the results obtained.

Between 1920 and 1925 the scientific staff of the School for Flight Surgeons published a considerable number of papers on the various aspects outlined above, but by 1925 the intensity of the research began to decline and the next three to four years can be designated a period of stagnation.

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*Cf.: D.A. Myers. The army med. bull. War department, Washington, No. 36, 1934; N.C. Gilbert and C.W. Green. Arch. int. med. Vol. 27, 1921; C.M. Robertson. Laryngoscope. Vol. 32, 1922; R. Dodge. J. exper. psychol. Vol. 6 No. 1, 1922; V.T. Scott. Mil. surg. p. 300, 1923.

This was due to some extent to the appearance of Bauer's book Aviation Medicine in 1925. (This book was excellently translated by Vasil'ev and published in Russia in 1927 and is well known to the Soviet specialist reader). Bauer's book incorporated the whole achievement of world aviation medicine during the first world war and the ensuing seven years. The three sections on the selection of pilots, aviation physiology and medical services gave all the most up to date information on the work of aviation doctors and the book included an extensive bibliography of 503 titles. As the standard textbook of aviation medicine at the time Bauer's book "nipped in the bud" the partisan activities of individual doctors in the literature and also directed thought in the direction of new and more extensive research for which methods had not then been elaborated. A gradual reduction in the spate of scientific works and the development of a state of stagnation in experimental research can be observed in the three years following the publication of Bauer's book.

It was not until 1929 that there was a revival among American aviation doctors and interest in aviation increased owing to new achievements in flying and the development of the aircraft industry. It was at this time that American aviation doctors formed an association of which Bauer was elected the president. In March 1930 this association began to publish the journal Aviation Medicine, which is still extant.

AVIATION MEDICINE IN OTHER COUNTRIES

It is a feature of the period between 1920 and 1930 that aviation medicine began to develop in other countries apart from the major capitalist powers.

Poland. In the initial of its existence Polish aviation medicine was under the direct and immediate influence of the French school. The papers presented by Polish doctors at the third, fourth and fifth international congresses on aerial communications were not remarkable in any way and did not go beyond general questions. Before 1928 Polish aviation medicine made an intensive study of the world literature and translated several works. Polish doctors paid particular attention to the work of Soviet doctors and translated many works into Polish, including the present author's The Mechanism and Chemical Effect of Rarefied Air (1927).

In 1928 Polish aviation medicine was under the direction of Gószcz, who is known to Soviet doctors for his thesis on caisson work during the construction of one of the main bridges over the Neva. It was as a result of his efforts that an institute of medical research in aviation was set up in Poland in 1930. The institute had departments of physiology, hygiene, clinical medicine and psychology. It was from this time that articles on the selection, physiology and hygiene of pilots and their liability to illness and injury began to appear in the Polish journal of military medicine (Missyura, Leoshko, Fiumel and others).

It is evident that all these organizational measures were prompted by the high accident and injury rate in the Polish air force. Astonishing figures on loss of pilots were published in the Polish press in 1931. Figures were given for the number of pilots who had finished training at flying school between 1919 and 1929. Of these only 10% were fully fit for flying duties in 1930 and the remainder had either crashed, been found entirely unsuitable or suffered partial loss of working capacity (35% suffered a 25-50% loss of aptitude for flying, 12% were found entirely unsuitable and 43% died in crashes)*.

Denmark. Although the Danish air force was founded in 1912 it was for long without a medical service and it was not until 1918 that medical selection of pilots based on psychological examinations was instituted. This work was carried out by the psychological laboratory of Copenhagen University.

From 1923 onwards there was relatively deep interest in the medical examination of pilots. Doctors attached to air force units who were also pilots began to play a consultative role in these examinations. It was not until 1933 when doctors were appointed to the major air force units that the air force medical service finally took on an organized form.

In order to be recognized as an aviation doctor a doctor had first to undergo training in a flying school and then take a special course at the physiological laboratory in Copenhagen University where he would learn the principles of high altitude physiology and study the method of altitude chamber work. This training was largely in the hands of Professor Krogh and his assistants Christenson, Nielsen and Asmussen.

Sweden. Until the 1930's there was no aviation medicine in Sweden. It was not until 1926 that the Swedish air force began to be organized and prior to 1936 it had only four units. In the next twenty years the number of aviation doctors scarcely reached fifty. No research on aviation medicine was carried out in Sweden and the work of the doctors was wholly based on German research. It was not until 1945 that the first altitude chamber was constructed in Sweden.

Australia. The Australian Air Force was founded in the middle of the twenties, at which time an air force medical service was also set up. The director of the air force medical service was also the director of the civil aviation medical service. For a long time there was no particular trend to the medical service of the Australian Air Force which was modelled on the British pattern. The only special feature was the use of aircraft to produce a medical service for the many cattle farmers and inhabitants of isolated localities (Flinn). Medical centers for this purpose equipped with ambulance planes, doctors and nurses were set up as early as 1926.

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*Accident Rate in the Polish Airforce. Vestnik vozdushuogo flota, No. 4, 1932.

It was not until 1940 that a research committee for aviation medicine was set up, this committee consisted of a number of departments concerned with the effect of altitude, rationalization of flying clothing, flying conditions in the tropics, fatigue, the effect of acceleration, lighting for night flying and other matters. From this time onwards the physiological faculties in the universities of Melbourne and Sydney began to play a considerable part in the study of physiological problems.

Thailand. The first squadron formed in Thailand in 1912 consisted of seven French aircraft. Only three of the pilots were Thais. By 1913 however the first military flying school had been set up in Bangkok. During the First World War some of the doctors serving with the Thai aviation units in France became acquainted with the elements of French aviation medicine but this remained without effect. Between 1918 and 1931 Thai pilots were examined in the Red Cross hospital and it was not until 1941 that three medical officers returned to Thailand after studying aviation medicine for three years in the United States and Europe. They were appointed as aviation doctors and began by translating Armstrong's book on aviation medicine into the Thai language. In 1949 a special building was erected for the air force medical service at Bangkok airfield. The service has four departments: physiological, political, staff and physical fitness. Since 1950 the air force medical service has published a bi-monthly newspaper.

Switzerland. Despite physical proximity and close contact with such countries as France, Germany and Italy where aviation medicine was being seriously studied no research was carried out in Switzerland before the Second World War. It is true that there are references in the literature to the effect that the Swiss aviation doctor Meyer-Müller developed a new method for the selection of pilots in 1922, but it has been impossible to ascertain exactly what he proposed. There was some study of the effect of oxygen deficiency at the research laboratory on the Jungfrau (height 3355 m) during the Second World War and the first mobile altitude chamber was constructed there. After the war Swiss aviation medicine developed under the influence of American aviation medicine and all the Swiss doctors were trained at the school of aviation medicine at Randolph Field. In 1949 the Swiss set up their own institute of aviation medicine at Dübendorf. The special features of Swiss aviation medicine are worthy of attention: total rejection of psychotechnical selection methods, extensive use of the psychiatric examination of pilots, systematic examination of hearing, since faulty hearing is treated in Switzerland as an occupational disease of pilots, careful study of the reactions of the cardiovascular system of pilots during flight by electrocardiograms transmitted direct to the aerodrome and study of the problem of fatigue and early wearing out of the organism in aircrew.

Aviation medicine also began to develop between 1920 and 1930 in Belgium, Holland, Hungary, Japan and a number of other countries. Unfortunately there is not enough material in the literature to establish the distinctive features of development in these countries.

ESSAY VII

THE GOLDEN AGE OF SOVIET AVIATION MEDICINE 1930-1940

The 1930s can fairly be called the golden age of Soviet aviation medicine. This was the decade when the country's aviation doctors tackled the medical aspects of flight with remarkable energy and originality. Institutes of scientific research on aviation medicine sprang up one after another. Several of the leading established research institutes - the Soviet Academy of Sciences, the Ukrainian Academy of Sciences, the All-Union Institute of Experimental Medicine, the Kirov Academy of Military Medicine and many others - were drawn into working on aviation medicine.

By the late 1920s a network of paramilitary psychophysiology laboratories had begun to take shape, particularly in the Air Force training schools. The establishment of a civil aviation Medical and Hygiene Service in 1930 led to the organization of psychophysiological laboratories attached to the Civil Aviation (CA) schools. The same year, 1930, saw the establishment of the CA Institute, with the Air Institute of Scientific Research attached to it.

By 1932 the Institutes of Scientific Research on Aviation Medicine functioning along Air Force lines comprised Sector IV of the Institute of Scientific Health Research (ISHR) (formed out of the Central Psychophysiological Laboratory) and a network of peripheral psychophysiology laboratories, while the CA Institutes comprised the CA Central Psychophysiology Laboratory, the Aviation Medicine Division of the Air Institute and a network of peripheral psychophysiology laboratories.

In the late 1930s further organizational changes took place. Chief of these were: 1) the establishment of the Institute of Aviation Medicine (IAM) in 1935 (out of Sector IV of the ISHR); 2) the establishment of aviation medicine departments to the Air Force administration and the introduction of flag officer rank for Air Force surgeons in 1937; 3) the expansion of the CA Central Psychophysiology Laboratory in 1935 and its conversion into the Central Laboratory of Aviation Medicine of the USSR People's Commissariat of Health in 1937; 4) the development of a department of aviation medicine attached to the Central Institute of Advanced Medical Training in 1939 and 5) the opening of an aviation department in the Moscow Second Institute of Medicine in 1939.

Aviation medicine now enjoyed high prestige among Soviet scientists. Research flourished, many flight doctors were involved in theoretical and practical work on the problems of aviation medicine, Party and public organizations were showing deep interest in these problems and constant help and attention were forthcoming from the Air Force and civil aviation authorities.

The number of flight doctors at this time was very large. Some of them became enthusiasts and adopted the new field of specialization as their life work, to which they devoted all their knowledge, energy and creative ability.

As in other matters, the expansion of scientific research on aviation medicine was part of the complicated process of transforming the Soviet Union from a backward to a powerful, industrialized state. Socialist industrialization provided the basis for an advanced national aviation industry.

During this period the Party trained a galaxy of talented designers who raised the national level of aviation to a very high standard. The names of Soviet aircraft designers of that period - A.N. Tupolev, S.V. Ilyushin, S.A. Lavochkin, A.S. Yakovlev, V.M. Petlyakov, A.A. Arkhangel'skii, P.O. Sukhoi, A.I. Mikoyan - and designers of aero engines - V.Ya. Klimov, A.D. Shvetsov, A.A. Mikulin and others - are known throughout the world.

In the period 1931-1933 several new types of aircraft appeared: in 1930 the Ya-4 and I-5; in 1931 the ANT-14, the Stal'-2, the MD-R-2 (ANT-8) and the Ya-5; in 1933 the Ya-7, the RD (ANT-25), the ANT-16, I-15 (I-153, Chaika), the Il-4, the IP-I, the Stal'-3 and others. By this time Soviet aviation already had the autogyro, designed by Kamov and Skorzhinskii back in 1928, and the helicopter, designed in 1930.

Under the five-year plans the aircraft industry expanded along with its scientific and technological foundations. New aircraft factories appeared, scientific research institutes were founded, an army of highly-qualified engineers, aeronautical technologists, designers and fliers was trained. This was when the Party, determined to develop Soviet aviation, told designers and fliers that their job was to fly higher, further and faster than anybody else.

Soviet aviators responded to the call. By 1940 they had established out of 168 international flying records - more than a third of the total. Their triumphs included the heroic flights to the Arctic camp at Chelyuskin in 1934, the 1937 flight of a scientific expedition to the North Pole, the historic flights of Soviet aviators across the North Pole to the USA and many others. Lastly, the men of the Soviet Air Force showed the world their prowess in the battles of Lake Khasan (1933) and the Khalkin-Gol River (1939) against the Japanese and in the 1939 Finnish War.

The period was therefore one in which aviation medicine could develop apace, because Soviet aviation was steadily growing and improving, the air fleets were being equipped with new machines and training problems were being successfully solved.

For the moment, it is not possible to give a detailed account of outstanding personal careers, nor have we access to material on the work of the numerous peripheral psychophysiological laboratories; but there is enough clear and vivid information on the major scientific research institutes to permit a brief description of them here. I shall not attempt to assess the contribution of each to the development of Soviet aviation medicine, but only to describe how they came into existence. I think this chronological approach gives a better picture of the history of Soviet aviation medicine and of the creative and successful search for solutions to the intrinsic problems of this branch of medicine.

THE AVIATION MEDICINE SECTION OF THE CIVIL AIR INSTITUTE OF SCIENTIFIC RESEARCH

The Air Institute of Scientific Research (AISR) was founded in 1930 as part of the CA Institute. On the insistence of N. A. Rynin one of its twelve sections was devoted to aviation medicine.

The organizational difficulties, as in other sections, were immense. There was no establishment, no building, no equipment. The organizational plan of the AISR contained no provision for permanent staff and the sole established unit in the section was the directorate (under A. A. Sergeev, Reader in air communications). The rest of the section staff were recruited on a temporary basis to do a particular approved job, after which they were either given a new job or dismissed from the section. Such a system might, perhaps, have been workable in a technical section engaged on specific practical assignments, but it was totally unsuitable for the aviation medicine section, for it meant that there was no permanent staff of laboratory workers to do the everyday routine work. But the AISR administration would not budge and throughout the six years of the section's existence staffing policy remained unchanged.

The restrictive policy prevented the AISR from developing its own scientific research laboratories. In any case, there were no premises for them and no money to equip them. The system meant that anyone recruited to work on a project did so not in the AISR building but wherever he could, usually at his principal place of work, where he could count on some facilities.

At first there was much discussion about the Section's function. The AISR administration, having no experience in aviation medicine, tended to copy the Air Force laboratories. The trend there was towards psychophysiology; so the administration edged the Section in that direction.

The Section fought hard for independence and the right to decide for itself the direction its work should take. From the outset, its members wanted to concentrate on physiology: in particular, on three main problems: the physiology of high-altitude flight, the physiology of blind flying and the physiology of night flying. Not until it had been functioning for two years did the need to tackle

certain psychophysiological problems arise, and then the work was dispatched fairly quickly.

Among the other sections of the AISR there was a special group of investigators, working in isolation from the rest and not directly connected with the aviation medicine section. This group was headed by N. A. Rynin. It consisted of A. A. Likhachev, M. M. Likhachev, V. M. Karasik, A. A. sergeev and N. A. Bogoyavlenskii. It had been formed in 1929, when Rynin at the Leningrad Institute of Communications (Department of Aerial Communications), had succeeded in building the first animal centrifuge in the USSR.

Long before then Rynin had been nurturing the idea of constructing a centrifuge. He realised that the future of aviation lay in altitude and speed and saw clearly that as the aeroplane became faster man would come up against the problem of accelerational effects. In one of his books on interplanetary communications (Superaviation and superartillery, 1929) he had written a special section on "The effects of acceleration", in which he refers, in particular, to Tsiolkovskii's experiments on centrifuging cockroaches back in 1891, which showed that these insects stood up well even to 300 g.

In the late 1920s Rynin, noting the steady increase in aeroplane speeds, decided to extend Tsiolkovskii's original experiments and to construct a centrifuge in which various animals could be subjected to the effects of acceleration. He did not succeed until 1929. Well aware that the real point of these tests would be the physiological experiment, Rynin invited A. A. and M. M. Likhachev, Karasik and myself to take part. In this way a group of people interested in the problem of acceleration grew up of its own accord in Leningrad. When the CA Institute was formed out of the former Faculty of Aerial Communications this group merged with the AISR.

Rynin built two experimental centrifuges, one with a 1-m radius, giving up to 300 r.p.m. and the other with a radius of 0.32 m giving up to 2800 r.p.m. In the spring and summer of 1930 these apparatuses were used for experiments on insects (flies, beetles, cockroaches), fishes (carp), amphibians (frogs), birds (siskins, pigeons, crows) and mammals (mice, rats, rabbits and cats). Since the animals were not fixed in a definite position while the centrifuge rotated, the tests revealed only the limit tolerance of centrifugal forces. The cats and rabbits were found to withstand 10 g for 2 sec, the white mice 12 g, the birds from 30.7 to 38.9 g, the frogs up to 48 g, the carp up to 28 g and the cockroaches up to 2500 g.

The results were published in 1931 in a paper entitled The effect of acceleration on living organisms. The animal tests, which were in effect the first attempt to study the question experimentally, had pointed the way for similar research on the human organism and this impelled Rynin to insist on his group's independence when the AISR was set up. One of the group's projects was to construct a large centrifugal machine. The physiologist members of the group had worked out the data for this and reached the conclusion that the radius

of the machine would have to be 5 m; at the distal end of the radius there would have to be a cabin where the subject could either sit or lie in a wide variety of postures; and the maximum permissible acceleration would be 20 g. At the same time, all the details of the tests, the equipment, instruments, apparatus and so forth were worked out.

Work was held up for lack of funds; lack of space in the AISR meant that Rynin had nowhere to put his centrifuges. In 1932 he suggested handing over the whole project to the Aviation Medicine Section, but refused to take part in the work himself.

Rynin's enthusiasm had cooled not only because of the technical and material difficulties but also because the people running the AISR never stopped expressing their scepticism. In the end the project for the first Soviet human centrifuge was stillborn and the Likhachevs, Karasik and Bogoyavlenskii left the AISR.

The project was not revived until 1933, when L.S. Troyanov joined the section. Through his efforts all the blueprints for the centrifugal machine were completed by 1934. They incorporated all that the physiologists had asked for. The machine, unfortunately, was not constructed, but the blueprints are preserved somewhere in the CA archives.

I have deliberately told this story in some detail, for if the machine had been built it would have been the first centrifugal machine not only in the USSR but in the world and would have provided opportunities for extensive experimental study of the effect of acceleration on the human organism.

At the outset the scientific staff of the organization consisted of V.V. Strel'tsov, P.I. Egorov, A.F. Aleksandrov and K.L. Khilov; later, they were joined by A.V. Lebedenskii, V.A. Gorovoy-Shaltan, N.V. Zimkin and A.M. Zimkina. Last of all, M.P. Brestkin nominally joined the section, but he did not stay long. These people were all young scientific workers with an excellent training in methods, who had been attracted by the prospect of scientific research in so novel and interesting a field as aviation. They were all on the staff of the Kirov Academy and its fine laboratory equipment was at their disposal.

Nearly everyone had his own particular project. Strel'tsov, Egorov and Aleksandrov were working on the physiology of high-altitude flight, Khilov on the physiology of the vestibular apparatus, Lebedenskii and Zimkin on the physiology of night vision.

Strel'tsov, at that time a member of the Academy's Physiology Department under Academician L.A. Orbeli, was a young scientist of brilliant promise. He had already completed several experiments, in the Department, on problems of general physiology, in which he had shown wide erudition and a mastery of experimental technique. He had not encountered the problems of aviation physiology until he joined the section in 1930, but he immediately realised that aviation offered a limitless and untouched field for research and for the rest of his life threw himself wholeheartedly into aviation medicine.

Strel'tsov stayed in the section only eighteen months, but that was long enough to arouse his deep interest in the problems of aviation medicine. At the end of 1931 he was transferred to Moscow and appointed head of Section IV of the Institute of Scientific Health Research, which had grown out of the Central Psychophysiology Laboratory of the Soviet Air Force. This appointment put him in charge of all scientific research work on aviation medicine in the USSR.

While he was in the section Strel'tsov carried out his first experimental research on the physiology of high-altitude flight. This was the starting-point for an immense number of research projects on oxygen starvation.

In his first paper, A contribution on carbon dioxide addition to the breathing air at high altitudes (1933a) he reported studies not of animals, but of a human subject breathing air with various concentrations of oxygen and carbon dioxide. The oxygen concentration had been reduced to 12-10% and the CO_2 concentration raised from 0.03 to 5.5%. The tests did not permit a categorical opinion on whether or not carbon dioxide should be added to the oxygen inhaled at altitude but they did give Strel'tsov a chance to reach a number of new and interesting conclusions. Dissatisfied with his tests on the inspiration of oxygen-impoverished gas mixtures, he raised, for the first time in the USSR, the question of building pressure chambers and suggested that it would be worth training fliers in such chambers so as to increase their resistance to altitude.

His second paper, The blood gases at altitude (1933b) was an excellent review essay, throwing detailed light on the current state of the problem of variations of gas composition and gaseous tension of the blood during ascents to high altitudes.

Egorov, who had left the Central Psychophysiological Laboratory and transferred to the Therapeutics Clinic of the Kirov Academy, eagerly responded to the section's invitation to return to his old, familiar field of aviation medicine. In collaboration with the inventor Aleksandrov he began to put into effect an idea which he had thought out long before, namely, the construction of a special portable instrument for determining a flier's "personal ceiling" or tolerance of acute oxygen starvation.

Such an instrument was needed because the USSR had no pressure chambers and the Henderson-Pierce rebreather apparatus was cumbersome. Egorov cherished the idea of equipping every flight doctor with a convenient instrument, which could be used under any conditions and would replace the flat oxygen bag, the Dreyer instrument and the Henderson-Pierce rebreather currently in use in other countries.

Such an instrument, called the EA-1, has been built back in 1931. This consisted of a 13-liter bag, CO_2 absorption boxes, an inhalation-exhalation valve and a mouthpiece. The respiratory bag was filled with atmospheric air and as

the oxygen from it was absorbed the subject fell into a condition of anoxia. The test lasted until the subject lost consciousness. This took 8 to 12 minutes, varying from one individual to another. The final oxygen level in the bag was 7-4%. Lengthy parallel verification tests in which the EA-1 and the Henderson-Pierce rebreather were both tried on the same individuals yielded roughly similar results. Three indices were used to assess the results of the EA-1 tests: the duration of the test in minutes, the final oxygen level in the bag and the reactions of the cardiovascular and nervous systems to oxygen deficiency. A detailed description of the instrument, the first tests and the technique of using the instrument were given in a paper by Egorov and Aleksandrov, Towards a technique of determining the organism's tolerance to reduced partial pressure of oxygen (1933).

The EA-1 was a prototype; the inventors gradually improved the instrument, producing, the EA-2, EA-3 and finally the EA-4.

During his five years' work in the section Egorov made an increasingly thorough study of the pathogenesis of altitude sickness and based his doctorate thesis, The influence of high-altitude flights on the flier's organism (1937) on research performed at the Central Psychophysiology Laboratory and in the section over a number of years.*

The EA-1 enabled the section to start experimental study of cardiovascular reactions to acute anoxemia. In 1932-1933 220 subjects were tested (143 fliers and 77 students). The subjects fell into three categories in terms of their responses to anoxia: good, medium and poor. The first group comprised subjects who withstood anoxia well; the pulse and blood pressure remained steady, the subject retained his sense of orientation for a long time and oxygen consumption was economic. Subjects in the poorly-tolerant group suffered a violent reaction of the cardiovascular system to comparatively slight reduction of the oxygen concentration in the bag, rapidly developing cyanosis, loss of orientation, neuropsychic disorders, spasms and syncope. The middle group showed borderline reactions between good and poor tolerance. Of the 220 test subjects, 30.5 per cent, 40.9 per cent and 28.6 per cent were classified, respectively, in the good, medium and poor groups. Tolerance was no better in fliers than in non-fliers (Sergeev, 1935).

With the EA-4 it became possible to study the influence of prolonged anoxia on the cardiovascular system. The subject could be kept at the "test altitude", that is, under conditions of roughly constant atmospheric oxygen concentration, for long periods. Admittedly, it was never possible to keep the oxygen concentration strictly constant with the EA-4, and after one hour it inevitably fell slightly. Nevertheless, the instrument did permit prolonged observation on the reactions of the cardiovascular system. Tests showed that exposure to oxygen deficiency for one hour did not elicit manifestations of

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*Egorov's works are discussed in more detail below (p. 162)

adaptation to low partial pressure of oxygen (the reactions of the cardiovascular system were roughly the same at the beginning and at the end of the experiment) and that, so long as the oxygen level in the ambient air was kept within 11-10%, cardiovascular reactions in healthy subjects remained fully compensated, broken compensation being observed only when the oxygen level in the air fell below 10% (Sergeev, 1936).

The problem of high-altitude physiology led the section to take an interest in oxygen apparatus. In 1930 there was still no such equipment of Soviet design and it was extremely desirable to start an experimental workshop to meet this need. The AISR administration, however, was reluctant, so the section began a detailed study of foreign instruments, with the idea of adopting any features that could later be incorporated in a Soviet-designed model. A detailed description of nineteen types of oxygen instruments appeared in 1933 (Sergeev, 1933).

One of the people to whom the section owed most from the very start was K. L. Khilov. In 1930 Khilov who combined the qualities of a first-class clinician with those of an equally first-class research man, was already the greatest otolaryngologist in the country. He was then studying the functions of the vestibular apparatus, with the aim of determining its importance in flight and seeing if it could be trained. These were questions of obvious topical importance. By the end of the 1920s investigators abroad were no longer exclusively preoccupied, and in the early days of flying, with the reactions of the vestibular apparatus, and had come round to the opposite view: namely, that the vestibular apparatus was not the leading factor in determining the position of a man in space. So by 1930 there were two diametrically opposed views on the importance of the vestibular apparatus in aviation. Khilov's aim was to settle this complicated problem.

He performed an immense number of tests on normal and decerebrated animals placed on a special table where they could be in any position and in a specially designed centrifuge. At the same time Khilov made a great many flights in a two-seater aeroplane, during which he studied his own reactions to various aerobatics.

Even in his first paper, On the role and importance of the vestibular apparatus in aviation (1933), Khilov had reached the conclusion that "the vestibular apparatus does not fulfill the physiological function of an orientating organ in the presence of centrifugal force; under heightened stimulation it can act as a disorientating apparatus, upsetting the pilot's ability to control his aircraft accurately". In the same work Khilov analyzed the mechanism of air sickness and concluded that it was due mainly to irritation of the otoconia, which elicited a series of vegetative and somatic reflexes setting up the complex of symptoms characteristic of air sickness.

At the same time, Khilov, on the suggestion of Dr. Gershman of Professor Voyachek's otolaryngological clinic, designed the celebrated "four-bar swings" with which he performed his tests on animals and human subjects. In his last years in the section Khilov extended and completed his research and in 1936 published his results in final form, in a paper entitled Vestibulometry

in aircrew selection. This paper presented the first formulations, in Soviet literature, of opinions on the role and importance of the vestibular apparatus in aviation, based on fundamental theoretical considerations. Briefly, these views amounted to the following: 1) in selecting pilots attention should be directed primarily to the function of the otoconia rather than to the semicircular canals; 2) during flight the otoconia function mainly by producing vegetative rather than somatic reflexes; consequently, analysis of the vegetative reactions must serve as the index to a person's suitability or unsuitability for flying duties; 3) subjects giving second or third degree reactions (pallor, cold sweat, nausea and vomiting) to the production of the otolithic reaction (OR) must not be admitted to flying schools; 4) on the other hand, subjects even with very pronounced somatic reactions should not be debarred; 5) given first degree vegetative reflexes or somatic reflexes of any degree, vestibular training on the four-bar swing is advisable.

These brief conclusions on the otolaryngological method of aircrew selection, together with the experimentally demonstrated possibility of training the vestibular apparatus, were highly unconventional at the time and turned the otolaryngologists' views on selection technique upside down. The result of Khilov's research was the most valuable and definitive doctrine on the physiology of the vestibular apparatus and its role in aviation was formulated in the USSR.

In view of the section's work on the importance of the vestibular apparatus in fliers a review essay became necessary, as a kind of addendum to Khilov's experimental research (Sergeev, 1933).

The problems of high-altitude flight physiology and the physiology of the vestibular apparatus thus dominated the section throughout its existence.

The third problem was that of night vision. A. V. Lebedenskii, already a brilliant scholar in this field, with an excellent physiological training obtained under Orbeli, tackled this problem. In his first paper, A contribution on the color illumination of the pilot's cabin (1933a) Lebedenskii had experimentally demonstrated that the most suitable illumination for the cabin was mixed white light, not exceeding 5 mc. At the same time, his research had shown that although long-wave light was best for maintaining high ocular sensitivity (condition of the dark adaptation), such illumination would be unsuitable in terms of eye fatigue, persistence of clear vision and speed in distinguishing details. At the same time, Lebedenskii gave his views on airfield illumination, training the sight for flying in poor light and so forth.

Again, these were unconventional conclusions for the time. The point was that in the late 1920s there was much discussion about cabin illumination in the literature of other countries; some authors were showing a preference for red, others for blue light. Lebedenskii's proposal to illuminate the cabin with mixed white light of low intensity was novel and unexpected. Subsequent experience proved him right.

Lebedenskii's second work, Basic functions of the eye under conditions of poor illumination (1933b), directly supplemented his first paper. Here he discussed in detail the doctrine of the dark adaptation, expounded the causes and mechanisms of adaptational changes and defined the variation of such visual functions as the resolving power of the eye, acuity of vision, persistence of clear vision, ocular accommodation and so forth under conditions of poor illumination.

Lebedenskii's career in the section was limited to his completion of these two pieces of work, but they were landmarks in the history of aviation medicine. They may well have been a turning point for Lebedenskii himself, for he remained engrossed in the problems of optical physiology for a long time.

The Zimkins' work was a direct continuation of Lebedenskii's. The suggestion that the pilot's cabin should be illuminated with mixed white light immediately raised the further problem of simplifying and rationalizing the dials of aircraft instruments. Rozenberg (1928b) and Dobrotvorskii (1933) had studied the psychophysiological rationalization of aircraft instruments before Zimkin took up this question, but they were concerned mainly with standardizing a rational arrangement of the instruments on the panel.

The Zimkins attempted a more detailed approach, based on psychophysiological evaluation. This involved an immense amount of time and effort in setting up experiments to evaluate instrument dials under various conditions of illumination, but finally they produced a series of valuable conclusions, indicating that most aircraft instruments were unsatisfactory. The basic requirements proposed by N. V. Zimkin for such instruments were as follows: 1) the object must have an angular dimension of not less than 1.5'; 2) the divisions and figures on the scale must have a stroke thickness of not less than 0.44-0.58 mm; 3) the strokes must not be less than two stroke thicknesses apart; 4) the number of divisions and figures must be kept down to the essential minimum; 5) no unnecessary legends indicating the maker's name, the instrument number, type and so forth, must appear on the dials; 6) the figures, divisions and arrows on the dials must shine. These basic conclusions were not published until 1937 (Psychophysiological evaluation of aircraft instrument dials).

Gorovoy-Shaltan worked in the section for about a year (1937). His subject was the very topical one, at that time, of techniques for determining flying aptitude. He concluded that it was quite insufficient to restrict the examination to determining the speed of a simple psychic response or even the speed of a selective response. For the pilot of a fast aircraft the speed of his reaction to moving objects might be decisive. Gorovoy-Shaltan therefore built a special apparatus for determining the speed of the motor reflex in response to a moving stimulus, accurate to approximately the ideal limit of time accuracy.

In concluding this account of the six years' work of the ASIR aviation medicine I must admit that the assignments were invariably of topical and vital

importance to aviation. The talented young people making up the team, who were to show their brilliance in the years to come, fully understood that aviation medicine could make a huge contribution to Soviet aviation and threw themselves wholeheartedly into the work. The results of the team's work were published in two symposia, Transactions of the aviation medicine section (1933). There can be no doubt that, given favorable conditions, the creative energy of this team could have flowed into extremely important and valuable research; but lack of premises, lack of a permanent staff of laboratory assistants and technical workers and lack of interest on the part of the ASIR administration gradually killed the section, and in 1935 it was abolished. All the same, it must be recognized that its work represented an important stage in the history of Soviet aviation medicine.

SECTOR IV OF THE SCIENTIFIC HEALTH RESEARCH INSTITUTE

In the late 1920s the Red Army Medical Administration had three large laboratories at its disposal in Moscow: the Red Army Central Psychophysiological Laboratory, the Air Force Central Psychophysiological Laboratory and the Central Laboratory of Health and Hygiene. At the end of 1929 and the beginning of 1930 all three were amalgamated by order of the Army Medical Administration to form the Scientific Health Research Institute. The Central Psychophysiological Laboratory of the Air Force became Sector IV of the new Institute. Its retiring chief, M.V.Rayevskii, was replaced by a man called Ivanov, who held the job for a year without contributing anything particular to the work or performance of the Sector.

Through the period 1929-1931 the Sector continued along the lines of the former Central Psychophysiological Laboratory. It came to life in 1931, when V.V.Strel'tsov was appointed as its chief.

Strel'tsov was one of Orbeli's most talented pupils and had received from him a brilliant physiological training. He was already familiar with the main problems of aviation medicine, for he had once worked for eighteen months in the AISR section of aviation medicine and he started work in Sector IV at the height of his creative powers. His deep devotion to the work, his awareness of the necessity for the Sector to expand and develop its own direction in aviation medicine, his great knowledge of physiology, combined with his tremendous energy, enthusiasm and capacity for work, brought new life to the Sector.

All the prerequisites were present. The establishment of the Institute gave the Sector an opportunity greatly to increase its establishment of technical staff and laboratory assistants, for the Central Laboratory had been understaffed in this respect. Moreover, by the time the Sector was organized the laboratory already had a solid nucleus of scientific staff who had already made a thorough study of problems in aviation medicine. Lastly, the Sector took over all the

technical and laboratory equipment which the Central Laboratory had gradually built up during the five years of its existence.

The key members of the scientific staff were A.P. Apollonov, V.G. Mirolyubov, N.A. Vishnevskii, I.K. Sobennikov, V.V. Andreev and the aviator Fedorov.

By the time the Sector came into being the Central Laboratory was in close liaison with the Air Force authorities, who saw in it a scientific center capable of working out a series of physiological and health problems of interest to aviation and kept giving it one assignment after another. These assignments called for new techniques, new equipment and, above all, an entirely new theoretical approach.

The previous five years' work of the Laboratory had made it abundantly clear that the former psychophysiological trend had not been justified. A radical change in the basic lines of the work was needed. Strel'tsov made that change.

As a pure physiologist, Strel'tsov had thoroughly assimilated Orbeli's fundamental idea, namely, that physiological functions must be studied from the angle of evolutionary physiology. Here was an opportunity for a completely new approach to disturbances of the physiological functions under conditions of reduced atmospheric pressure and for new thinking about the aviator's reactions to altitude. With his team solidly behind him, Strel'tsov spent the whole of the next fifteen years demonstrating the soundness of this conception through an endless series of research projects. His efforts and those of his coworkers gave the Soviet Union the lead in developing a theory of the influence of rare air on the human organism, a theory which consolidated the innumerable unrelated data on the disturbance of various physiological functions at altitude into a coherent general picture. While aviation physiologists elsewhere continued to accumulate such data but had no basis for a broad theoretical interpretation, the Soviet school was able, during the decade 1930-1940, to elaborate an original, broad and coherent theory of the influence of reduced atmospheric pressure on the human organism.

It was Strel'tsov who took the lead in building up this picture. Relying on the basic principles of dialectical materialism and making extensive use of Marxist-Leninist philosophy, he started an entirely new and extremely fruitful trend in Soviet aviation physiology and kept to it all his life.

Not unnaturally, this new trend called for new, more refined techniques. The rebreather was no longer adequate as a means for studying the effects of reduced partial pressure of oxygen, despite Apollonov's efforts to improve the device, and the time had come to install a pressure chamber.

The necessity for such a device had occurred to Dobrotvorskii and Egorov back in 1928, but no plans for building one had been made until the

following year and the pressure chamber was installed only in 1930. This was the first pressure chamber in the Soviet Union and it opened up a new epoch in research on the effects of reduced atmospheric pressure on the organism.

On 29 August 1932, using this pressure chamber, Strel'tsov became the first man in the USSR to "ascend" to an altitude of 1300 m. Before the end of the year he had used the device to prove, for the first time, that it was possible to train an aviator to tolerate high altitudes. In the same pressure chamber Apollonov successfully tested the first Soviet oxygen apparatus. Lastly, this was the pressure chamber which enabled Apollonov and Mirolyubov to draft and publish the first instructions on medical precautions required for high-altitude flights. In short, the construction of the pressure chamber started a whole new epoch in the history of Soviet aviation medicine and enabled researchers to develop a broad frontal attack on the problems.

The objective conditions for giving a basically physiological direction to the Sector's work had been built up; and with the onset of the boom period in Soviet aviation, roughly at the end of the 1920s, the research men were impelled to investigate the problems of altitude physiology.

The growth of Soviet aviation was an integral part of the Communist Party's great industrialization plan. Party and Government, concerned about national defense, inaugurated a series of measures for the development of aeronautical engineering, which resulted in the rapid growth and consolidation of the national aircraft industry. With the expanded activity of the Central Institute of Aero-Hydrodynamics (CIAH), under the directorship of Academician S. A. Chaplygin, a series of new aircraft, interesting from the design point of view, was produced. Their designers were the best in the country: A. N. Tupolev, P. O. Sukhoi, A. A. Arkhangel'skii, V. M. Petlyakov, A. N. Putilov and many others. In 1934 they built the ANT-20 ("Maksim Gor'kii"), the ANT-40 (SB), the MBR-2 and the ANT-22 (MK-1); in 1935, the I-16, the UT-2, the DAR and the TsBK-26; in 1936 the UT-1, ANT-35, ANT-40, TsBK-19 (Il-17), Stal'-7, Stal'-11, Pe-8, Il-2 and I-17; in 1937 the KhAI-1, OKO-1, MDR-5, MTB-2 (ANT-44) and others.

In 1928 Soviet aviators and Soviet aircraft had started to compete with those of Western Europe; they now won a series of world records. The most outstanding flights were the following:

1) in September 1932 a group of aviators under the command of Suzi, flying Soviet aircraft, made the first group high-altitude flight in a jet stream, at an altitude of 5000 m, from Moscow to Khar'kov and back; Strel'tsov himself went with the expedition to test the performance of the first Soviet oxygen apparatuses;

2) in August 1933 Sokolov-Sokolenok and Zazymov made a high-altitude flight from Moscow to Sevastopol' and back maintaining an altitude of 5000-5800 m for 11 hours;

3) on 30 September 1933 the stratosphere balloon "USSR", piloted by G. A. Prokof'ev, K. D. Godunov and E. K. Birnbaum ascended to 18,600 m;

4) on 30 January 1934 the Soviet stratosphere balloon "Osoviakhim" piloted by P. F. Fedoseenko, A. B. Vasenko and I. D. Usyskin, rose to an altitude of 22,000 m;

5) in February 1934 the aviators N. P. Kamanin, A. V. Lyapidevskii, M. V. Vodop'yanov, I. V. Doronin, S. A. Levanevskii, V. S. Molokov and M. T. Slepnev made their heroic rescue of the Chelyuskin expedition;

6) in September 1934 M. M. Gromov, flying a machine designed by Sukhoi and called the RD* set up a non-stop flight world record by flying 12,411 km in a closed circuit in 75 hours 2 min;

7) on 7 September 1935 V. N. Evseev established an all-Union record by flying 12,020 m;

8) on 21 November 1935 V. K. Kokkinaki set up a world altitude record at 14,575 m;

9) in 1936 V. P. Chkalov, G. F. Baidukov and A. V. Belyakov flew a set course from Moscow to Nikolaevesk on the Amur, via Franz Josef Land and Kamchatka, in an ANT-25, covering the distance of 9,374 km in 56 hours 20 minutes;

10) in the same year, 1936, a series of load-altitude records was started by Kokkinaki, who flew a twin-engined Tsk B-26 carrying 500 kg of freight at 12,800 m; he was followed by Alekseev in a TsAGI-40, who flew a 1,000-kg freight at an altitude of about 12,700 m; next, A. Yumashev took a four-engined TsAGI-6 airship carrying 500 kg to an altitude of 9,000 m; then M. Nyuktikov and M. Lipkin, flew a four-engined monoplane, designed by V. Bolkhovitinov, at 7,000 m with 10,000 kg on board; lastly, the same two aviators reached an altitude of more than 4,500 m with a record load of 13,000 kg;

11) in March 1937 M. V. Vodop'yanov, V. S. Molokov, I. P. Mazuruk, A. D. Alekseev, P. G. Golovin and D. Kruze took a transport to the north polar station;

12) in 1937 Chkalov, Baidukov and Belyakov made a remarkable flight from Moscow to America over the North Pole, covering a distance of 10,148 km in 62 hours 17 minutes and setting up a flight record for distance in a straight line.

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*Russian initials standing for "Long-distance record" - translator.

The mere enumeration of these remarkable achievements shows the immense strides that had been taken in the nation's aircraft industry and in the training of aircrews and the vast amount of preparatory work done by Soviet fliers, engineers and designers.

That the Soviet school of aviation medicine, and in the first place the Sector IV team, made a definite contribution to these achievements is not in doubt, for it was doing detailed work on such problems as oxygen supply, medical precautions in long-distance flights, aircrew selection and health surveillance work and rest regimes, rational feeding, the use of stimulants and so on.

For various reasons, the bulk of the Sector's work was not published and it is therefore impossible to discuss it in detail; but there is no doubt that its main work concerned the organism's response to high altitude. The clue lies in the fact that the first Soviet oxygen apparatuses did not go into production until 1931-1932.

During this period the Air Force High Command and the research men themselves were specially interested in two questions: 1) personal altitude ceilings, or the individual's ability to fly at more or less high altitudes without oxygen and 2) the possibility of training a flier's resistance to altitude factors. For Sector IV these two questions had urgent priority. They called for an immense amount of experimental work and occupied the attention of Soviet aviation physiologists for a long time.

Some light was thrown on the first question in a monograph by Egorov, Pereskokov and Raevskii entitled The aviator's altitude ceiling, published in 1931. This work, however, was based on results obtained by a number of doctors, seconded to the Central Laboratory (Pivovarov, Romanovich, Knokh, Kuntsevitskii, Piunovskii, Sevast'yanov, Tyunyaev and others), who had worked with the unmodified Henderson-Pierce rebreather during the early years of the Laboratory's existence (up to 1928). Many of their conclusions were obviously not entirely reliable: for example, they regarded it as doubtful whether individual altitude tolerance was limited to the reduction of atmospheric pressure to 253 mm Hg and succeeded in showing that a large group of subjects tested could withstand a reduction to 240-230 mm and in individual cases even to 126 mm. Since 240-230 mm corresponds to an altitude of 8700-9000 m and 126 mm to an altitude of 12,850 m these conclusions were clearly dubious.

The defects of the Henderson-Pierce apparatus were clear to Apollonov, who had done a great deal of work with it. The main difficulty was that the subject could not be kept at a uniform altitude for a reasonably long time with this instrument. To solve this problem Apollonov, in conjunction with Gamburg, introduced modifications to the rebreather permitting an additional supply of oxygen (instead of water) so that the test subject could be kept at a given altitude for a relatively long period. In other words, the instrument in its new form could be used to determine not only an individual flier's ability to withstand oxygen deficiency ("personal ceiling") but also his "working ceiling" - how long he could retain his working capacity at a given altitude. This was a tremendous

achievement for the time and the Apollonov-Gamburg paper, Rebreathing test for determining the working ceiling of a flier (1931) was regarded by all flight doctors as a highly promising advance. The pressure chamber, however, was a much more perfect instrument and once it was built interest in the rebreather sharply declined.

The people mainly engaged on the second problem, training aircrews in pressure chambers to improve their altitude tolerance, were Strel'tsov, Apollonov and Gurvich. Their work, started in 1931, gave an impetus not only to the continuous research in progress in Sector IV but later also to the Institute of Aviation Medicine. Their successes in training fliers in the pressure chamber and the theoretical soundness of the idea that the physiological adaptational mechanisms could be modified by ground training to improve tolerance converted Strel'tsov into an ardent supporter of this method. For the rest of his life he never ceased advocating it among fliers and flight doctors and was constantly developing and improving ground-training techniques.

In a series of works published between 1932 and 1936 Strel'tsov constantly drew attention to the effectiveness of pressure-chamber training and it was through his efforts that it became officially recognized and included in the instructions on altitude training for aircrews. It was solely because of his insistence that the authorities authorized the large-scale production of pressure chambers and their installation at all large airfields and it was solely due to his striking demonstrations that the method won wide support among flight doctors.

Strel'tsov's interest in the physiology of high-altitude flight resulted in the publication of a series of papers, mainly in the Vestnik vozdushnogo flota and Voenno-sanitarnoe delo. In his very first paper, A contribution on the effect of reduced barometric pressure on the organism (1933a) Strel'tsov showed, for the first time the urgency of this problem for Soviet aviation and pointed the way to solving it. In the same year he published a paper on Physiological notes on high-altitude flights, in which he adduced experimental data from his own experience in a pressure chamber at an altitude-equivalent of 13,000 m. In this paper he mentioned, again for the first time, the onset of painful sensations in the joints of the upper and lower extremities at altitudes above 10,000 m. Other new contributions were his reasoned inference that at altitudes above 4000-4500 m fliers would have to breathe oxygen and that pressure-chamber training was both useful and advisable.

Strel'tsov developed, added to and refined these propositions in later works: Oxygen sources and oxygen apparatuses (1934c), High and very high altitude flights (1934b), Achievements in the physiology of high-altitude flights (1935b), High-altitude flights (1935c) and the chapter on High-altitude flight in a book by Krotkov and Galinin, Military medicine (1936).

In these works Strel'tsov constantly referred to his own and his coworkers' experimental findings, urging the necessity of trying to improve the flier's operational capacity at a given altitude. In 1935 he was the first to demand the

creation of high-mountain physiological stations, aircraft laboratories, temperature-pressure chambers for experimental work and so forth.

All this shows that the physiology of high-altitude flight had become Sector IV's principal concern. It inevitably involved the team also in the problems of altitude precautions and therefore in designing oxygen apparatuses.

The job was handed over entirely to Apollonov, who from 1931 to 1954 took an active part in designing and improving Soviet oxygen apparatuses. Every new model came into his hands and remained there until its physiologic specifications had been exhaustively listed. Apollonov inaugurated endless pressure-chamber tests and performed endless research on the alveolar air at various altitudes. As a result, the first Soviet oxygen apparatus, the KPA-1, designed in 1931, was rapidly replaced by the KPA-3, which was in turn replaced by the KPA-3 bis. The latter apparatus remained in use for eight years, until it was replaced by the improved demand-regulator apparatuses during the Second World War.

Apollonov's work in improving oxygen apparatuses had immense importance for the development of Soviet aviation. The excellent qualities of the KPA-3 bis enabled Soviet aviators to fly up to altitudes of 10 to 11,000 m and gave Kokkinaki an opportunity to set a world altitude record in 1935.

It is a matter of profound regret that hardly any of Apollonov's work was published.

Apart from his research on pressure-chamber training and his work in improving oxygen apparatuses Apollonov completed a further series of research projects during his time in the sector, notably on aircrew performance in gas masks and on the work of pilots flying regular schedules. This work too remained unpublished.

The high-altitude physiology work entailed bringing in other senior members of the Central Laboratory staff. One of these was N.A. Vishnevskii, the creator of Soviet aviation-ophthalmology.

Up to 1931 Vishnevskii had still been engaged mainly in working out aircrew vision norms, but in that year he turned his attention to the study of night vision. His extraordinarily thorough treatment of problems connected with the special difficulties in semi-or almost total darkness is shown in the series of papers he wrote in 1932 and 1933: The night map (1932a), Rational illumination of the pilot's cabin in night flights (1932b), Physiological notes on night flights (1933).

As these works were unimportant, however, they did not make Vishnevskii's name. His real contribution to aviation medicine came only when he started experimental research to discover how reduced atmospheric pressure affected the various functions of the organ of sight. Jointly with B.A. Tsyrlin he

was able to prove that under conditions of anoxia a series of visual functions was disturbed (Vishnevskii and Tsyrlin, 1935a). The dark-adaptation curve runs at a much lower level at 5000-6000 m than at ground level; for completely clear visual perception at these altitudes the illumination required is 13 microlux, against 3 at ground level. Color vision is drastically impaired at such altitudes and, in particular, green and blue are perceived as gray. These disorders, however, are completely cured by inspiration of oxygen. These investigations were a new and important landmark in Soviet aviation medicine. The results were published in works by Vishnevskii and Tsyrlin, Functions of the eve in night flights at high altitude (1933), Light signalling in the Air Force (1934) and The effect of reduced barometric pressure on the dark adaptation, color vision and ocular electroexcitability (1935a). The publication of the last-named paper in the Physiological journal of the USSR emphasized the importance of this research for the whole of Soviet science.

Extremely interesting research on functional disorders of the central nervous system at altitude was done by I. K. Sobennikov. His work, unfortunately, was not published.

No less interesting were A. N. Krugloi's observations on variations in the motor-periodic activity of the intestine under conditions of anoxia. His experiments were the first to establish the depression of the motor-periodic activity of the stomach in hypoxia and the complete restoration of this function through inspiration of oxygen.

Lastly, V. G. Mirolyubov and I. A. Chernogorov (1934), also members of Sector IV, pioneered altitude electrocardiography in the USSR.

All these multifarious projects were directed to one end: to discover more about the physiological effect of reduced atmospheric pressure on the organism and so help to elucidate the difficult problems of high-altitude flight. As I have shown, the Sector's scientific team, inspired by Strel'tsov's passionate enthusiasm, made a concerted effort to win new ground in aviation physiology and put immense energy and originality into its work.

The main direction of the Sector's work was clearly physiological, but this does not mean that other lines of enquiry (clinical, psychophysiological) were neglected. They were kept going by the increasing demands in regard to aircrew recruitment, but they were of secondary importance, compared with the physiological trend. A rudimentary interest in hygiene did not develop strongly.

The men who advocated and cultivated an interest in the clinical aspects of high-altitude flight were Mirolyubov, Sobennikov, Vishnevskii and Kulikovskii. In the main, this trend expressed itself in the improvement of aircrew selection and examination methods.

There were people both in the Central Psychophysiological Laboratory and in Sector IV who kept up a steady interest in the problems of aircrew selection and examination; their work led to a gradual improvement in selection methods and to a series of orders establishing new minimum health requirements.

The pamphlet issued by the army medical authorities in 1929, Medical examination of aircrew personnel, also required amendment. Members of the Sector worked out a more detailed procedure, which was published in 1932 under the title Handbook on procedure for examining aircrews and flying-school entrants. This manual remained in force until 1939, when it was replaced by a new Manual for members of Air Force medical boards.

An immense amount of work went into those improvements. Several considerations had to be taken into account: first, Soviet aviation was becoming increasingly important and it was essential to ensure that aircrews should be physically fit; secondly, it was essential to keep a constant check on the aviator's ability to operate despite various functional disturbances; thirdly, it was essential to keep pace with clinical advances in the understanding, evaluation and interpretation of various morbid manifestations; lastly, it was necessary to keep up with the extensive experimental work in progress in aviation medicine, so as to be in a position to introduce its results into the flight surgeon's practical work. On all these counts the Sector did a good job.

The various orders and regulations standardized methods of purely clinical selection, but they contained no indications whatsoever in regard to psychological, psychotechnical or psychophysiological selection. Not that Sector IV had shelved these matters, even though they were not given the priority they had enjoyed under Mints or treated on a par with medical selection, as in the early days of the Central Laboratory's existence; nevertheless, the Sector still had its methods of psychophysiological investigation. A psychophysiological examination was obligatory in candidate selection, but the results were not taken into account at all in assessing the candidate's suitability or unsuitability. Most members of the Sector, including Strel'tsov, already regarded it as obvious that psychophysiology (in reality, psychotechnics) was out of date, but for some obscure reason they had not been able to get away from it completely.

Not until the 4 July 1936 Resolution of the Central Committee of the CPSU (B) On pedagogical distortions in the system of the Peoples' Commissariat of Education was psychotechnics finally debunked as a pseudoscience.

The hygiene trend started to develop in Sector IV, very tentatively, under V.V.Andreev, who inaugurated important research on the hygiene specifications of various types of aviation fuel. In 1933 he published Leaded gasoline and rules for working with it and Aviation fuels and their hygiene specifications (1936a). On the strength of his experimental work the Army medical authorities issued special instructions on leaded gasoline in 1933.

What distinguished the Sector as a team was its readiness and ability to take up each new problem presented by the vigorous growth of Soviet aviation. Parachuting, for example, was a new development and it was a natural reaction by Mirolyubov and Sobennikov that they immediately realised the necessity of studying its medical implications. Admittedly, the Kirov Academy of Military Medicine became interested in this subject almost at the same time and created a special team, consisting of Aleksandrov, Ivanov, Kabanov, Lebedinskii, Livshits, Makarov and Skoblo, which produced several interesting reports published in 1932-1934 (Aleksandrov, Ivanov et al., 1932; Makarov, 1934, etc.). The Academy's interest in parachuting, however, was casual and short-lived.

Sector IV's was not. Within three years Sobennikov, in collaboration with Mirolyubov, had personally published four papers on the training of parachutists, precautions against injury in parachuting, the organization of parachuting camps, the effect of the jump on the organism, the hygiene of parachuting, the psychophysiological characteristics required of parachutists and the medical precautions needed in parachute jumps (Sobennikov, 1933a, 1933b; Sobennikov and Mirolyubov, 1936). They were the first to work out parachuting-aptitude indications and contraindications, which were fully incorporated in the first instructions on the selection of parachutists, issued by the Army medical authorities in 1932.

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In the five years of its existence Sector IV of the Scientific Health Research Institute worked steadily and energetically on the problems that were then most acute and urgent in medical aviation. In its experimental work the Sector kept to the fundamental tenets of Soviet physiology and concentrated on a number of practical problems. The close contact maintained between practice and advanced theory created a situation in which practice constantly raised new questions calling for thorough experimental study; conversely, experimental findings were promptly applied in practice.

The days of groping for the right path were over. The old Central Laboratory had suffered from a certain lack of confidence and indecision, but the Sector IV team stood firm on the ground of physiology, hygiene and clinical studies.

It was obvious that the Sector had outgrown its narrow framework. The range of problems submitted to it, the volume of work and the high qualifications of its members made expansion imperative. The first to realise this was Strel'tsov and in 1932 he called for the establishment of a special institute of aviation medicine.

It took three years of persistent argument, endless discussion and correspondence before it was finally decided whether the new institute should come under the Air Force or the Army medical authorities. Strel'tsov argued that it must come under the Air Force, so as to keep it in closer touch with aviation and form an integral working part of that service; but the Army medical authorities insisted, and when the Institute of Aviation Medicine was established in 1935 it was subordinated to them. The new Institute found no place for Strel'tsov, nor for the Sector's most active member, Apollonov.

PHYSIOLOGIC CONDITIONS FOR STRATOSPHERE BALLOON FLIGHTS

The idea of constructing a Soviet stratosphere balloon appeared almost simultaneously in aeronautical circles in Moscow and in Leningrad, although the initiative had first come from Moscow. The two centers worked along different lines. In Moscow it was primarily the military who undertook to design and test a balloon and to work out all the flight details; in Leningrad the project was run on civil lines, mainly by Osoviakhim, and therefore advanced rather more slowly. By September 1933, when the Moscow stratosphere balloon "USSR" made its successful flight at 18,600 m, intensive work on the Leningrad project was still in progress.

Just as the individual engineers and aeronautical teams in Leningrad were working completely independently of those in Moscow, so too were the people responsible for ensuring physiologic conditions for the crews of the balloons. Neither team had any experience of the specific problems involved in stratosphereic flight, but their nature was clear and all that was needed was experimental verification and refinement of formulation. Since the basic problem amounted to ensuring physiologic conditions for a number of men to survive in a restricted closed space, it was obvious that experimental research would take roughly the same course in both centers and that the main conclusions would be roughly the same.

The physiologists had six main objectives: 1) to establish the pattern of rise in the carbon dioxide level in the air in a narrow, restricted, hermetically sealed gondola containing several men when atmospheric pressure fell to 500 mm Hg; 2) to establish the pattern of fall in the atmospheric oxygen level in the gondola; 3) to devise methods of eliminating atmospheric carbon dioxide in the gondola; 4) to select the most suitable and economic method of replacing the oxygen used up; 5) to devise methods of controlling humidity; 6) to devise a system for feeding the crew, design emergency rations for use in case of a landing in deserted terrain and think out the problems of clothing, medical supplies and the disposal of excreta.

These questions faced both teams. From the physiological point of view their solution would have presented no difficulty had it not been for one complicating factor: in the interest of reducing weight the designers of the stratosphere balloon had decided that the cabin would have to be sealed not while the bottom was still on the ground but at some physiologically permissible altitude, for example 3000, 4000 or 5000 m. This made things more difficult, because at that time there were no data to show what would happen to the physiological processes in an hermetically sealed space at subnormal atmospheric pressure. It became clear that the solution to all the problems listed above would depend on a series of experiments.

The historical interest of this experimental research is threefold: this was the first time Soviet aviation medicine had to face the problems of stratospheric flight; it was the first time that experiments were set up to determine the oxygen consumption and carbon dioxide evolution in a closed car where the atmospheric pressure would be reduced to 490-500 mm, and these experiments were later to be used extensively in designing aircraft cabins; lastly, the Soviet aviation doctors worked out the problems of stratospheric flight along absolutely independent lines. A further reason why the story is worth telling in some detail is that it marked the beginning of M. P. Brestkin's active career in aviation medicine; he was later to become one of the country's leading experts in aviation physiology.

The Moscow and Leningrad physiology teams were working almost simultaneously and completely independently. It is a great pity that neither published all their results. This prevented their findings from being adequately used later and, incidentally, makes it impossible to give a comprehensive account of their work here.

The following notes on the Moscow team are based solely on the short papers published by its members. As the author was a member of the Leningrad group and can therefore draw on personal recollections as well in regard to that team, the account of it given here is somewhat fuller than that of the Moscow team.

The Moscow Team

The Moscow physiologists' team consisted of members of Sector IV of the SHRI, chief of whom were Strel'tsov, Apollonov and Gurvich.

The first experiments were made in a pressure chamber, the capacity of which had been determined in advance. Two or three test subjects were chosen, of roughly the same build as the stratosphere balloon crew, the chamber was closed, the air in it rarefied to the altitude equivalent of 3000 m and the test subjects kept under these conditions for 4-6 hours; during this time a constant watch was kept on the increase in CO_2 concentration and reduction of oxygen

concentration. Under these conditions the volume of air in the chamber was 1.5 m^3 per man, roughly the same as would be available in the actual flight.

By a series of tests it was established that after 3-1/4 hours the CO_2 concentration had risen to 4.6% and the oxygen concentration had fallen to 16.1%. This meant that in 3-1/4 hours two test subjects had exhaled 138 liters of CO_2 and inhaled 156 liters of oxygen; that is, CO_2 evolution was 21 liters per man per hour and oxygen intake 24 liters per man per hour at 3000 m.

These figures, repeatedly checked and found correct, were sufficient to yield a definite conclusion about the conditions under which the crew would be able to work. On the assumption that the crew would consist of three men, each requiring 1.5 m^3 of air, on the average, the investigators faced two problems: how to get rid of the CO_2 from the air in the gondola and how to maintain normal physiologic partial pressure of oxygen.

Preliminary calculations based on earlier tests had shown that to ensure physiologic conditions for the crew the gondola would have to be supplied with 70 liters of oxygen per hour and that 63 liters of CO_2 would have to be removed from it each hour. If the oxygen supply could have been limited to 70 liters per hour the question would have been extremely simple. Two 3-liter bottles containing oxygen compressed to 150 atm, would have been enough, even allowing for a pressure correction of 10 atm, to give 840 liters of oxygen, sufficient even for a 10-hour flight.

But it was essential to make a series of corrections to cover every conceivable accident, particularly the possibility of a leak in the gondola, which would mean slightly raising the pressure in it; it was therefore decided that the oxygen reserve in the gondola would have to be greatly increased, to 5000 liters. If this were taken in the form of compressed gas, eight 4-liter oxygen bottles would be needed. But the weight of these bottles would be about 100 kg too heavy a handicap. The team therefore came to the conclusion that some of the oxygen reserves would have to be taken in liquid and some in compressed form. The advantage of liquid oxygen, from the weight point of view, was obvious: three liters of liquid oxygen weighs altogether about 9 kg and yields 3000 liters of gaseous oxygen.

After detailed study it was decided to take 3-liter Dewar flasks of liquid oxygen (3000 liters) and, in addition, three 4-liter bottles containing compressed oxygen (1800 liters), connected to individual KP-1 oxygen apparatuses.

The problem of providing enough oxygen in the gondola to keep the ambient oxygen concentration normal was solved at the same time: it would be sufficient if the ambient air were replenished with 1 liter of pure oxygen per minute.

The problem of eliminating accumulated CO_2 was rather more complicated. To renew the ambient air it was obviously going to be necessary to drive it through some kind of facility containing a good CO_2 absorber. The solution was found by creating a special ventilation apparatus consisting of an electrically-driven blower which would drive the air through six extractors containing CO_2 absorbers.

Soda lime, capable of absorbing 150 m of CO_2 per kg, was used as the absorber. On the above-mentioned figure of 21 liters of CO_2 per man per hour, 3 men would exhale 630 liters of CO_2 in 10 hours, 4 kg of soda lime would be enough to absorb 600 liters of CO_2 and so, allowing for a reserve of 2 kg, the team concluded that 6 kg of good-quality soda lime would be enough for a 10-hour flight by a crew of three. The absorbers were housed in six cylindrical containers fitted with grids.

The electrically-driven ventilation system was designed to ensure a current of 150 liters of air per minute through these extractors. This meant that the hourly rate of air renewal in a 4 m^3 car would be 2.25.

Pressure-chamber tests showed that the CO_2 level could be reduced from 3.5% to 1.6% in one hour by this apparatus; so with 6 absorbers it would be enough if the ventilation apparatus was switched on for 20 minutes in every hour of flight. After 6 hours of flight the extractors would have to be changed.

All these experimental data were verified by tests in a stratosphere balloon car carrying three men. The tests lasted 3-1/2, 4-1/2 and 10 hours and corroborated the experimental findings. It could therefore be taken that the problem of ensuring physiologic conditions for the crew of the stratosphere balloon had been correctly solved.

Humidity control in the cabin was an extremely acute problem. The team worked on it for a long time without success.

Sanitation presented less difficulty and there was no need for experiment. For food it was decided that the crew should be supplied, with one day's ration

of solid food and one liter of liquid per man in the form of coffee, tea and boiling water (in thermos flasks). A first-aid kit was designed. It was recommended that clothing be confined to woolen underclothes and woolen overalls (fur flying suits were rejected). Lastly, the team recommended that several rubber urine bottles be carried on board.

That the right solution had been found to all the physiological problems was shown by the brilliant flight of Prokof'ev, Godunov and Birnbaum in the "USSR" at an altitude of 18,600 m on 30 September 1933.

The conclusions reached by the Moscow team were published in papers by Apollonov, Gurvich and Strel'tsov (1934, 1935) and in a paper by Strel'tsov published in the Transactions of the All-Union Conference on Study of the Stratosphere (1935a).

The Leningrad team

In Moscow the job of solving the physiological questions of stratospheric flight had fallen to Sector IV of the SHRI; in Leningrad it fell to the Aviation Medicine Section of the AISR. The reason was that Rynin was now head of the team in charge of the stratosphere balloon project. In February 1933 he had approached the Section with the proposal to form a team of physiologists and to find an institute in Leningrad with an air-tight chamber that could be used for the tests. The team, consisting of four members of the Aviation Medicine Section, Brestkin, Egorov, Lebedenskii and Sergeev was formed and on 22 February 1933 submitted a memorandum to the chief design engineer, E.E. Chertovskii, containing theoretical calculations of the probable oxygen consumption and CO_2 evolution in the gondola. The memorandum explained the theoretical considerations underlying the team's assumption that the same method would have to be used as in submarines. It was proposed that all the experiments be made in the pressure chamber at the Kirov Academy's Physiology Department. Orbeli, head of the Department, agreed to this and later, as the work developed, officially acted as the team's adviser.

At the same time the team drew up a work schedule allowing two to two and a half months for the job; but in the event the work was held up by a series of complications connected with the manufacture of the ventilation apparatus, delivery of the CO_2 extractors and so on, and not finished until September 1933.

All the tests were made on members of the team, members of the balloon crew or the designers of the balloon. Altogether, 34 tests were made, either in the pressure chamber or in the balloon car.

In the early days several pilot experiments had to be made to find out the qualities and defects of the pressure chamber itself, test the apparatus and determine the CO_2 concentration curve.

In the first test Egorov and Sergeev stayed in the 3.5 m^3 pressure chamber for 2-1/2 hours at a pressure of 480-500 mm Hg. The tests immediately revealed that the rubber padding of the hatchway was not sufficiently air-tight, for the pressure in the chamber slowly increased.

The rubber padding was replaced and a second test performed, in which Egorov, Lebedenskii and Sergeev stayed in the chamber for 2 hours 10 minutes at a pressure of 520-550 mm. Analysis of air samples taken at the 30th, 90th and 120th minutes yielded the following results:

30th minute	CO_2 1.5%	O_2 19.43%
90th "	CO_2 2.5%	O_2 18.4%
120th "	CO_2 4.6%	O_2 16.2%*

*All the figures here and for the later tests have been converted for a pressure of 760 mm.

During this time the air temperature in the car rose by 3.5°. The sensations of the men in the pressure chamber included a sensation of heat in the facial region 30 minutes after the test started, difficulty in breathing after it had been going on for 70 to 80 minutes and a feeling of heaviness in the head, some slowing down of the mental processes, so that it took longer to solve multiplication problems involving three-figure numbers at the 97th minute, very pronounced difficulty in attempts to read aloud, due to shortness of breath at the 110th minute, and slight deafness at the 120th minute. No variations at all were observed in the cardiovascular system. The pulse rate increased slightly in the first five minutes in rare air but reverted to normal by the end of the second hour.

From this and a series of subsequent experiments the pattern of rise in the CO_2 concentration over a period of two to two and a half hours in the chamber without renewal of the air was established, along with the corresponding pattern of lowered oxygen concentration.

On the average, the CO_2 exhalation per man per hour was 15.7-18.25 liters at a pressure of 760 mm and the oxygen intake under the same condition was 19.2-94.5 liters.

The next problem was to determine the CO_2 and oxygen thresholds, for actual flight conditions CO_2 evolution and oxygen consumption would be rather than the figures given above, as the crew would have to perform a good deal of physical work. In addition, it was essential to provide against any possible failure of the ventilating system.

The indices to tolerance of high CO_2 concentration combined with oxygen deficiency were the subject's general feeling, the pulse rate, the blood pressure, the pulmonary ventilation and certain psychophysiological responses.

Here is a record of one of these tests.

Test of 1 April 1933

In chamber: M. P. Brestkin, B. I. Egorov and A. A. Sergeev.

Time	
07.15	Air starts to rarefy.
07.20	Pressure 480 mm. Air analysis: CO_2 - 1.0%, O_2 - 19.8%; psychometric indices: 17.9-14.7; pulse rate: Brestkin - 90, Egorov - 84, Sergeev - 87; pulmonary ventilation, 3 min: Brestkin - 32.84 liters, Egorov - 34.68 liters, Sergeev - 30.45 liters.
08.00	Pressure 485 mm; psychrometer - 20.1-17.1; air: CO_2 - 1.95%, O_2 - 18.2%; pulse: Brestkin 90, Egorov - 84; Sergeev - 72; pulmonary ventilation: Brestkin - 39.88, Egorov - 35.27, Sergeev - 34-26 liters; psychological tests revealed no perceptible change in the course of the mental processes.
08.33	Pressure 492 mm; psychrometer - 21.0-18.4; Air: CO_2 - 3.0%, O_2 - 17.2%; pulse: Brestkin 78, Egorov - 70, Sergeev - 78; pulmonary ventilation: Brestkin - 38.62, Egorov - 61.75, Sergeev - 39.8; slight increase in time taken to solve problems.
09.00	Pressure 506 mm; psychrometer 21.5-19.0; air: CO_2 4.0%, O_2 -

16.1%; pulse: Brestkin - 56, Egorov - 72, Sergeev - 72; pulmonary ventilation: Brestkin - 47.5, Egorov - 62.38, Sergeev - 43.43; a match was lit in the chamber but quickly went out; again, very slight increase in time taken to solve problems.

09.20 Pressure 115 mm; psychrometer 22.0-19.8; air: CO_2 - 4.9%, O_2 - 15.0%; pulse: Brestkin - 66, Egorov - 72, Sergeev - 68; pulmonary ventilation: Brestkin - 52.34, Egorov - 69.77, Sergeev - 51.69; increase in time taken to solve problems: all three men felt heavy and suffered from labored breathing; a match would not light.

09.40 Air starts to thicken.

09.45 End of test.

A series of similar tests on the same subjects revealed no notable alteration in the condition of the organism until the CO_2 level in the gondola had risen to 2.0-2.5% and the oxygen level had fallen to 18.0-17.0%; the subjects retained their full capacity to work under these conditions and felt comfortable. Further rise in the CO_2 level and lowering of the oxygen concentration led to dysphonia; the subjects no longer felt comfortable and their mental and physical powers were impaired. A CO_2 concentration of 6.5% and an oxygen concentration of 13.45% were taken as the tolerance limits; it was accepted that no further rise in the CO_2 concentration or reduction of the oxygen concentration could be tolerated. The conclusion was that in practice the CO_2 concentration could be allowed to rise to 2.0% and the oxygen concentration to fall to 18.0% at a pressure of about 500 mm in the car, but that at this point the crew would have to take action to renew the air paying particular attention to reducing the CO_2 concentration. There was no great difficulty in solving the oxygen-supply problem. Assuming that the gondola was sealed off at an altitude of 3300-3400 m, the partial pressure of oxygen in it would be 100 mm. To raise this to normal it would be necessary for the oxygen level to be not 20% but 30-32%, while at a pressure of 500 m the partial pressure of oxygen would be 150-160 mm. The next question was how much oxygen would have to be provided to raise the ambient oxygen level to 30-32% and how often it would be necessary to renew the oxygen reserves.

Both questions could be solved by simple calculations, once the total volume of the gondola and the number of people who would be in it were known. The team nevertheless thought it essential to test CO_2 tolerance under conditions of near normal oxygen concentration.

Several tests showed that if the amount of oxygen used by one man in one hour was 19.2-24.5 liters, three men would use between 145 and 183 liters in 2.5 hours. A current of 150 liters of oxygen was passed into the chamber several times. This amount kept the oxygen level relatively high but was clearly insufficient to raise it to 30-32%. Nevertheless, the principal adverse factor under these conditions was not the oxygen deficiency but the CO_2 excess.

The team calculated that it would be possible to start from an hourly oxygen demand of 24.5 liters at 760 mm, that is, 37.2 liters at a pressure of 500 mm.

This meant that for three men 735 liters of oxygen would be required for 10 hours at a pressure of 760 mm. Further, the oxygen would have to be used in a closed car at 3000 m, so as to raise the partial pressure of oxygen in the car to 150-160 mm. If the air volume in the car was 6 m^3 and the oxygen level at the moment the car was closed was 20% it would be necessary to raise the oxygen level to 30%, in other words to add 10% to the amount already present in the air of the car. This meant 392 liters of oxygen at 760 mm or 600 liters at 500 mm pressure. Consequently, the total amount of oxygen required for 10 hours' flight for three men was 735 + 392 = 1127 liters at 760 mm pressure.

The tests also established the time when it would be necessary to add oxygen. Proceeding from a maximum oxygen intake per man per hour of 24.5 liters at 760 mm or 37.2 liters at 500 mm pressure, it was clear that after one hour's flight in the closed car the air in it would contain 111.6 liters less oxygen than at the moment the hatch was closed. In other words, the ambient air would have been impoverished by 1.85% of oxygen.

On investigation the team rejected liquid oxygen, on the grounds that although it was lighter in weight it would be too dangerous if it accidentally spilt in the car, and recommended steel bottles containing compressed oxygen. They decided that these should be of low capacity (0.7 liters) on the following grounds: 1) if the capacity of the bottles was small it would be possible to release all the oxygen in them without using a reducer and in this case each bottle would release 105 liters of oxygen; 2) small bottles would constitute excellent ballast and therefore their weight need not be included as part of the dead weight. On these grounds it was decided to use 10 0.7-liter bottles containing oxygen compressed to 150 atm and, in addition, one 4-liter bottle. This would give an oxygen reserve of 1650 liters at a pressure of 760 mm, enough to keep the crew alive and active for a minimum of 15 hours' flight.

The problem of eliminating accumulated CO_2 from the car was far more complicated. A number of lengthy tests in which the CO_2 concentration was raised to 6.55% established a "standard" CO_2 exhalation per man per hour of

15.7 to 18.25 liters. In their subsequent calculations the team proceeded from a maximum figure of 18.25 liters at 760 mm pressure, which gave 27.9 liters at 500 mm pressure.

At the same time it was established that the CO_2 concentration permissible in practice was 2.0% at 500 mm, which meant a 10 mm partial pressure of CO_2. Even so, the team thought this concentration undesirable and based its tests on the necessity of eliminating all CO_2. This meant finding a way of absorbing 547.5 liters of CO_2 at a pressure of 760 mm in 10 hours of flight. The problem of CO_2 absorbers now became acute. The team immediately rejected liquid absorbers as inconvenient to use; nor did it regard as feasible Orbeli's suggestion of lining the car with felt impregnated with caustic alkali solution. Two possibilities remained: either to equip the crew with individual respirators of the gas-mask type or to use special extractors containing a good CO_2 absorber, through which a special ventilating device would periodically drive the air. Both methods were experimentally tested.

The first tests showed that the gas-mask method was in practice unsuitable. The apparatuses absorbed CO_2 well but they reduced the working capacity of the wearer and caused a number of unpleasant sensations: increased salivation, forced silence for many hours at a time, some difficulty in breathing and so forth. Replacing the mouthpiece by a mask made little difference.

A series of tests showed that by using individual insulating devices it was possible to stay for a fairly long time in a closed air-tight space without danger from high CO_2 concentration. This method, however, was rejected on the grounds mentioned above and it was decided to use a ventilation facility to absorb the carbon dioxide.

The requirements from this facility would be the following: its weight and volume must be critically small, sufficient volumes of air must be able to pass through it, it must not require much fewer and it must be simple to operate and reliable. Such an apparatus was designed and built. It consisted of a metal tube with 12 branches, laid along the floor of the car in the form of a ring.

The diameter of the tube in its various parts was so calculated that the amount of air passing through each branch per unit of time would be identical, so as to ensure even functioning of the extractors. These, containing the absorber, were mounted in the branches of the tube and the air from the car was

pumped through them by means of a duraluminum ventilator weighing 2.8 kg. The ventilator was operated by a motor (0.1 h.p., 12 volts) run off accumulators. It could also be rotated manually.

It took a long time to determine the optimum rate at which the air current must flow through the extractor. If the air flowed too quickly the extractors would inevitably let through some CO_2; if it flowed slowly, all the CO_2 might be absorbed but the total amount of air passing through the extractors would be insufficient. It was essential to find the rate at which CO_2 absorption would be complete while the total amount of ventilated air would be adequate. After a series of tests with the extractors intended for use in the flight, it was found that the optimum rate of flow was 90-100 liters of air per minute. The ventilation apparatus could circulate 1 m^3 of air per minute through the system if driven by motor and 0.5 m^3 per minute if rotated manually.

The design of the absorber and of the extractor itself was the result of numerous experiments, resulting in the choice of soda lime containers, capable of absorbing 50-60 liters of CO_2 at 760 mm pressure.

There were now sufficient data on which to base CO_2 control in the stratosphere balloon car. Given an exhalation rate of 27.9 liters per man per hour at a pressure of 500 mm, or 18.25 liters at a pressure of 760 mm, three men would exhale 547.5 liters at the latter pressure during a 10-hour flight and the apparatus would have to absorb that amount. Ten extractors with an absorption capacity of 50-60 liters each at 760 mm would therefore be sufficient; but the extractors would gradually permit some of the CO_2 to filter through, as the gas accumulated in them, and it was therefore decided to take 40 liters as the practical absorption limit and remove the extractors before they were completely saturated. It was finally decided to take 24 extractors on the flight, enough to eliminate CO_2 from the air in the car for approximately 17 hours.

The last problem in this series was to decide when the ventilator should be switched on and how long it should operate. This too was settled experimentally. It was established after a number of tests that with three men in the car the CO_2 concentration at the end of the first hour would be about 2%. If the ventilation apparatus was then switched on and kept operating for 10 minutes the CO_2 concentration in the air would be reduced to 0.5%. This timing was adopted.

Finally, a long test was made on 5 June 1933 to verify the solutions obtained. Ivanov and Sergeev remained in the chamber for 7-1/2 hours. Fifty

liters of oxygen were added to the air in the chamber each hour, the ventilator was switched on for 15 minutes per hour, to drive air through three extractors, and every half hour air samples were taken. During the experiment the oxygen concentration in the chamber fluctuated between 16.65 and 22.95% and the CO_2 concentration between 0.4 and 3.6%. High oxygen concentrations were obtained immediately the oxygen was fed into the chamber; high CO_2 concentrations were obtained during a period when ventilation was interrupted owing to a breakdown of the motor. The absorption power of the extractors was found to be excellent: the reduction in CO_2 concentration was 0.8%, 2.1% and 3.1% after 20 minutes ventilation with one, two and three extractors, respectively; 30 minutes ventilation gave a reduction of 2.8% with two extractors and 4.0% with three.

Once these data had been established it was decided to start training the crew for flight conditions. This training had the dual purpose of obtaining further data, relating to the stratonauts themselves, and of giving them genuine training for actual flight conditions. Several training exercises were performed, conditions being made extremely severe in some of them, in order to determine the individual tolerance to possible eventualities in the actual flight (reduced atmospheric pressure, increased CO_2 concentration, reduced oxygen concentration, high temperature and humidity in the car). The following is the record of one such test.

Test of 27 June 1933

In chamber: Fedoseenko, Vasenko, Egorov and Sergeev.

07.16 Chamber closed, air starts to thin.

07.20 Pressure 458 mm;

07.23 Pulse: Fedoseenko - 84, Vasenko - 90.

07.24 Fedoseenko's pulmonary ventilation 22.8 liters in 3 minutes at a pressure of 462 mm and a temperature of 23°.

07.32 Vasenko's pulmonary ventilation 44.4 liters (3 minutes, 463 mm, 23°).

07.46 Air analysis: CO_2 - 1.8%, O_2 - 19.8%

07.49 Pulse: Fedoseenko - 78, Vasenko - 96.

07.52 Fedoseenko's pulmonary ventilation 27.6 (3 minutes, 470 mm, 23.5°).

07.58 Vasenko's pulmonary ventilation 37.8 liters (3 minutes, 472 mm, 25°).

08.15 Air analysis: CO_2 - 3.5%, O_2 - 16.8%.

08.16 Pressure 476 mm. All suffer dyspnea.

08.19 Pulse: Fedoseenko - 78, Vasenko - 102.

08.24 Temperature in the chamber 25.5°. Match lights but quickly goes out.

08.45 Air analysis: CO_2 - 4.85%, O_2 - 15.2%.

08.46 Pulmonary ventilation: Fedoseenko - 52 liters (3 minutes, 480 mm, 25.5°).

08.53 Pulmonary ventilation: Vasenko - 63.6 liters (3 minutes, 480 mm, 25.8°).

08.55 Pulse: Fedoseenko - 84, Vasenko - 84. All breathing heavily.

09.07 Pronounced dyspnea in all, but experimenters and stratonauts all retain their working capacity.

09.08 Pulmonary ventilation: Fedosenko - 58.8 liters (3 minutes, 487 mm, 26.0°).

09.10 Pulse: Fedoseenko - 84, Vasenko - 80.

09.14 Pulmonary ventilation: Vasenko - 91.2 liters (3 minutes, 488 mm, 26.8°).

09.15 Walls of the chamber covered with large drops of moisture. Match will not light.

09.17 All suffering from severe dyspnea, pain and vertigo accompany movements, but no abrupt fall in working capacity.

09.18 Air analysis: CO_2 - 6.55%, O_2 - 13.4%.

09.19 Air starts to thicken.

09.23 End of test.

A series of training tests under various conditions showed that the calculations had been right, that the absorbers functioned excellently, regulating the gas composition of the air well over a period of 6 to 8 hours and that under these conditions the crew continued to feel well and fully able to work.

The last stage was to set up a long test in the gondola itself, simulating actual flight conditions, with the crew aboard. It was decided to make the test more severe by increasing the number of people in the car to six; Brestkin, Ivanov and Sergeev joined the three stratonauts Fedoseenko, Vasenko and Usyskin. The experiment lasted 6 hours, but this represented a 10-hour test of the air-renewal equipment and of all calculations based on a three-man crew. I shall not give the detailed record of the experiment, which took place on 19 August 1933, but the results were extremely good, despite the exceedingly aggravated conditions (six men, very crowded car, considerable rise in humidity, very high temperature - up to 29.2°, manual operation of the ventilator). The highest CO_2 concentration in the car was 2.7% and the lowest oxygen concentration 16.2%. All the subjects felt perfectly fit throughout the experiment and only the high temperature and humidity caused them discomfort. No important deviations were observed in the breathing and the cardiovascular system; mental and physical powers were unimpaired.

Although the test had shown that the problems of ensuring physiologic conditions for stratospheric flight had been solved correctly, it confirmed previous indications of the necessity for constant humidity control. This proved the most difficult problem and the team did not succeed in solving it completely.

On the basis of data well-known in physiology it was taken that the amount of moisture evaporated by the lungs and skin at 15°C by three men would be about 20 g and 222 g, respectively, in one hour, so that 242 g of water vapor could reach the ambient air each hour and the total amount for 10 hours would be 2420 g.

The team thought it essential to counter this excess humidity. A series of experiments was made to determine moisture absorption by sulfuric acid and calcium chloride. After the first test sulfuric acid was rejected on safety grounds. Calcium chloride did not give the good results expected (by the end of a long test the air humidity in the cabin had reached saturation point), but as the team had not managed to test silica gel, it was nevertheless decided to use calcium chloride, if only to reduce the air humidity during the first hours of flight. Tests showed that one metal extractor filled with 300 g of calcium chloride and sodium sulfate mixture absorbed altogether 30 g of water when the ventilator was operating for 32 minutes, provided 120-130 liters of air passed through it.

Lastly, the team had to deal with the problems of food supply and the disposal of excreta. The food supply presented no difficulties at all: the ration consisted of roast meat, rich pastry, white bread, chocolate and fruit. For excreta disposal it was proposed to use two metal vessels with tight-fitting lids, one with a capacity of 3 liters for urine and one of 4 liters for feces. Acidified solution of potassium permanganate could be poured into the latter vessel as a deodorant.

The Leningrad team finished its work in August 1933. The Osoviakhim balloon made its flight on 30 January 1934. During this flight Fedoseenko, Vasenko and Usyskin ascended to a record altitude of 22,000 m. From the entries in Vasenko's diary it can be seen that the physiological condition of the men who tragically died was excellent right up to the moment of the disaster - practical confirmation that the Leningrad team of physiologists had produced the right answers to all the questions they had been dealing with.

The team's results were published in a short paper by Brestkin, Volokhov, Egorov, Ivanov, Lebedenskii and Sergeev (1934) and reported to the All-Union Conference on Study of the Stratosphere (Brestkin, 1935).

THE CENTRAL SCIENTIFIC PSYCHOPHYSIOLOGICAL LABORATORY FOR THE STUDY OF CIVIL AIRCREW EFFICIENCY

The Civil Aviation Central Psychophysiological Laboratory for the study of aircrew efficiency was opened in 1932. Its title was changed in 1936 to "Central Civil Aviation Laboratory of Aviation Medicine", then to "USSR Peoples' Commissariat of Health Central Laboratory of Aviation Medicine" and again in 1941 to "Central Experimental Laboratory for Aviation Medicine, Civil Aviation Board of Health and Hygiene".

These changes in title were due to a number of reasons which will be apparent from the following account. The last change was due to the division of the laboratory into two parts in 1939, one responsible for physiological and health problems, under the Civil Aviation Scientific Research Institute and the other engaged mainly in experimental work. The latter became fully independent.

When the Central Laboratory came into existence there were already several peripheral laboratories on the model of the Air Force psychophysiological laboratories, attached to the civil aviation flying schools. Their original task, like those of the Air Force, had been psychophysiological (more accurately, psychotechnical) aircrew selection. The first such laboratory had been organized through the efforts of Ya. F. Samter in 1951 and was attached to the First Flying School at Bataisk. Samter himself, one of the greatest of Soviet flight surgeons, had a brilliant career for many years at this school.

A little later, in 1932, similar laboratories were established at the Second and Third Flying Schools at Tambov and Balachov, respectively.

For the first three years of its existence (1932-1935) the Central Laboratory could not decide what its work was to be. Those in charge had high enough scientific qualifications but absolutely no knowledge of aviation and no ability to apply their knowledge in this new special field. The result was that for three years the Laboratory was engaged in purely organization questions and in making

tentative efforts to find the right kind of work to do. During these three years there were three different chiefs, starting with Orlov, who was succeeded in 1933 by A. V. Aisenberg, who was in turn replaced by A. Z. Zalevskii in 1934. Not until 1935, when Strel'tsov, who had not been taken on the staff of the newly-formed Institute of Aviation Medicine, was appointed as chief, did the Central Laboratory really come to life.

The Laboratory had nevertheless selected an excellent staff during the 1932-1935 period. This team started to produce results only after Strel'tsov's appointment. The first scientific members of the laboratory staff were S. G. Gellershtein, E. S. Diligenskaya, V. V. Levashev, A. A. Mironova, D. S. Ozeretskovskii, D. I. Pisarev, Ya. F. Samter, S. I. Slonevskii and K. A. Tereshkovich.

During this period the Laboratory's work took three directions: psychophysiology, hygiene and clinical (experimental).

The psychophysiological or, more accurately, psychotechnical work was performed mainly by Gellershtein and Samter. The latter published seven papers during this period, on the practical application of psychophysiology to aircrew selection. His enthusiasm for aviation and keen interest in this new problem can be seen from the titles: Psychophysiology and the flying school (1932), Training flight aptitude (1933), Vocational selection in flying schools (1933c), The rationalization of vocational selection in flying schools (1934), Psychophysiology of parachuting (1936). As we see, Samter, like most doctors of the time, was suffering from the peculiar "infantile disease" of a passion for psychophysiology, a stage which, it seems, all aviation doctors had to pass through. Samter did not find himself and his true vocation in aviation medicine until Strel'tsov came to the laboratory.

The hygiene department, on the other hand, took the right, realistic direction from the start. Under S. I. Slonevskii it not only built up a core of experienced hygienists, consisting of V. V. Levashev, A. A. Mironova, A. V. Zakharova and K. N. L'vov, but also carried out a series of interesting investigations which are still of value to this day.

Slonevskii and his coworkers were engaged on problems of immediate urgency for aviation. Chief of these was the problem of flying clothing. Every aviator had good reason to know that existing flying clothing was unsatisfactory. In his first published work, Hygienic requirements from special clothing for aviation workers (1933), Slonevskii clearly formulated a series of problems requiring immediate work and in the following years he produced a number of practical solutions. In 1935, for example, he devised, jointly with Levashev, a mask for protecting the flier from freezing. In the same year these authors started studying a group of problems connected with the improvement of hygienic conditions in the cabin of an aircraft, the equipment of the cabin, the pilot's working space and the purity of the air in the cabin. After detailed study of these questions on the PS-9, P-5, K-5, Stal'-2 and other aircraft they formulated the basic hygienic requirements for the pilot's cabin and suggested ways of rationalizing it. Levashev published a series of interesting papers on emergency

rations for aircraft (1935), aircraft ventilation (1937), aircraft hygiene (1939a) heating and ventilation of aircraft (1938a and b). All this put him in the front rank of Soviet aviation hygienists.

The problem of rationalizing flying clothing was solved by Mironova and Slonevskii, who published the following works: Electrically-heated pilots' clothing (1936), Hygienic evaluation of aircrew clothing (1937), Methods of measuring temperature in the layers of an aviator's clothing (1937), An experiment in evaluating the thermal properties of flying clothing (1938), New kinds of material for special air-crew clothing (1939) and so forth. The painstaking research described in all these papers formed the basis for fundamental propositions about the requirements of the flier in regard to clothing and remains of interest to hygienists to this day.

During the same period, Slonevskii, jointly with Zakharova, started studying the operational health and hygiene conditions in special-purpose aviation. Their work on this subject too (Operational health and hygiene conditions in airborne chemical malaria control, 1937) still remains important.

If we add to the above list Slonevskii's pioneering work on airport sanitation (1939) and L'vov's proposals for aircraft disinfection and insect control (1939a and b), it becomes clear that the Laboratory's hygiene department was working energetically and to some purpose in the period 1932-1939. So clear-cut and realistic was the direction of its work that Strel'tsov's arrival in 1935 made no fundamental difference in this department, the only one not in need of reorganization.

The experimental department spent the first few years of its existence in practical work on aircrew examination. At first, its staff were guided by the current Air Force orders and regulations and did not feel the need for any special standards for civil aircrew. Gradually, however, it became clear that this was needed and such provision was finally incorporated in Civil Aviation Order No. 692 of 5 September 1934, listing the diseases and physical defects constituting disability for flying duties in the civil air service.

The division had spent the years 1922 to 1935 accumulating experience and learning about aeronautics, with the result that its scientific research work was minimal. Diligenskii and Filippovich published a paper on the cardiovascular reactions in parachute jumping in 1933; Litinskii published his first investigations on night vision and the rational illumination of the cabin (Litinskii and Il'ina, 1934a and b). In the following years Litinskii's work was to cover a very wide field.

Until 1935, then, when Strel'tsov came to the Laboratory, only the hygiene department was working intensively. The moment Strel'tsov arrived the Laboratory came to life and two or three years later its work was in full swing. Strel'tsov's first act was to open a new physiological department, staff it with highly-trained workers and greatly expand the scientific research program.

He was a passionately keen investigator and imparted his own vitality and enthusiasm to the whole Laboratory. Under his wise direction it began to function with the smoothness of a machine. Strel'tsov brought all his experience of organizational and scientific research work to the Laboratory and in a very short time achieved what many directors fail to achieve, a smooth working relationship among the members of his team. Fired with his energy and enthusiasm this team made unprecedented progress in the years 1935 to 1939, published a series of works and laid a firm foundation for experimental aviation medicine in the Soviet Union.

Long before this, when he was working in Orbeli's department, Strel'tsov had conceived the idea of studying the course of physiological functions from the standpoint of evolutionary physiology. Under conditions of reduced partial pressure of oxygen, the physiological functions and morphological formations developed last in the course of phylogenesis would be the first to support, whereas those physiological functions which were the oldest, from the phylogenetic point of view, would possess relatively high resistance to hypoxia. Since the cerebral cortex was phylogenetically the most recent formation, it would be logical to assume that functional disorders of the cortex and disorders of the higher nervous activity under hypoxic conditions would set in before the reactive modifications of the other physiological systems were disturbed. Moreover, since different parts of the central nervous system had developed at different periods of phylogenesis it must be assumed that the reactions of these parts to oxygen insufficiency must follow a definite sequence, strictly corresponding to the sequence of their phylogenetic development. Strel'tsov devoted five years of his work in the Laboratory to experimental verification of this conception.

This was a new idea, which could have come into existence only in a society viewing the world about it from the standpoint of dialectical materialism and basing its science chiefly on creative Darwinism, with Pavlov's doctrine on the higher nervous activity as the lodestar for all the natural sciences.

Strel'tsov's conception of the early vulnerability of such phylogenetically young formations as the cerebral cortex under conditions of oxygen insufficiency acquired specially important significance.

It had long been known that a number of psychic functions were soon disturbed at high altitudes, the discovery was not an achievement of Soviet aviation physiology. The achievement of Soviet aviation physiology, was to offer a possibility of thorough and complete understanding of the physiological processes developing under conditions of reduced atmospheric pressure. Soviet aviation physiologists had progressed from fact-finding to fact-interpretation and the formulation of conclusions. The main credit for this was Strel'tsov's.

He succeeded in interesting not only the Laboratory's physiologists but also the clinicians in the problem of anoxia. Even the old-guard psychophysiologists were converted and tried to use their own customary methods to

determine the effect of hypoxia on the higher nervous activity. The hygienists were the only group in the Laboratory who did not come within range of Strel'tsov's physiological ideas; even so, he was highly successful in arranging for them to work on problems of higher priority than in the past.

In his own field, which we have just described, Strel'tsov made extensive use of physiological experiment on animals and human subjects, pioneered the wide application of biochemical investigation techniques in aviation medicine, introduced histological techniques for the first time and used chronaximetry, clinical and psychophysiological methods. His dream of using electroencephalography was, unfortunately, not realized. In his work on the effect of hypoxia on the cerebral cortex his first search was for objective and reliable anoxemia indicators. He soon came to the conclusion that lack of oxygen must first tell on the higher functions of the brain and on the analyzer functions.

The question of hypoxic effects on the higher nervous activity was dealt with by Samter (1938a), by Ozeretskovskii and Tereshkovich (1938), and by Gellershtein, Ozeretskovskii and Tereshkovich, (1941).

Samter (1938a, 1939d) demonstrated that the memory was greatly impaired at altitude. The ability to retain numbers in the memory deteriorated considerably. At 5000 m, 59 per cent of the test subjects suffered some impairment of the memory, at 6000 meters the percentage rose to 78 and at 7000 m to 100 per cent.

Ozeretskovskii and Tereshkovich (1938), experimenting with 13 men at an altitude of 5000-6500 m, obtained data indicating progressive disintegration of the neuropsychic activity at altitude, pronounced depression of the cortical functions and consequent release of the diencephalic-subcortical apparatuses.

Subsequent research by the same authors together with Gellershtein (1941) led them further in the same direction. They obtained objective evidence showing that the mental processes slowed down at altitude, in that it took more time and effort to perform any activity; the subjects found difficulty in understanding a slowly-read text and concentration was reduced. At the same time it was observed that the subjects' critical evaluation of themselves became less acute, their movements were no longer smooth and rhythmical, they became impulsive, developed a tendency to make patently wrong decisions, suffered from reduced willpower and so forth.

The fact that the cortical cells were the first to suffer lesion at altitude was experimentally verified in a series of investigations by Parfenova in 1937-1939. Investigating neonate mice and rats, she reduced the pressure to tenths of a millimeter Hg and found that the animals could remain under these conditions for many minutes without suffering any loss of the elementary nervous functions in subsequent growth. Strel'tsov (1938a) interpreted these results as objective proof of his proposition that the primitive central nervous system was extremely insensitive to lack of oxygen.

On the basis of Parfenova's experiments, which had shown that in neonate animals spasm did not occur at altitude, Strel'tsov put forward the hypothesis that spasms due to altitude were of cortical origin. This was subsequently confirmed (1939) by experiments performed jointly by Strel'tsov and Nechayev, who extirpated a rabbit brain layer by layer and established that after the greater part of the cortex had been removed the animal did not go into spasm at altitude.

All these experimental data led Strel'tsov (1940e) to the conclusions that at altitude there was a "gradual and very delicate layer-by-layer disconnection of the brain from the topmost layers of the cortex down to the subcortical ganglia", a sort of "functional decerebration".

It is easy to see the basic idea underlying all Strel'tsov's work here: the key role in the organism's reactions to anoxia belonged to the cerebral cortex. Yet Strel'tsov made no attempt, in his conclusions based on this conception, to apply Pavlov's doctrine in interpreting his own experimental findings. It seems strange, too, that during this period he also made no attempt to use the conditioned-reflex technique to evaluate disorders of the higher nervous activity.

The Laboratory paid particular attention to research on the receptor function. The most noteworthy work performed in this direction concerned the effect of lack of oxygen on the function of the visual analyzer. Research in this direction, started in 1933 by Vishnevskii and Tsyrlin while Strel'tsov was still in Sector IV of the SHRI, was expanded and carried further by Litinskii (1936-1938) and Galler (1938-1948).

It was found that above 1500 m the dark-adaptation curve progressively fell, the sensitivity thresholds of the photoreceptors rose, and that color perception was impaired and disappeared completely at 6000 m. At the same time the ocular accommodation, convergence, measurement and depth perception as well as the electroexcitability of the eye were found to alter.

Strel'tsov's analysis of functional disorders of the vision led him to the conclusion that they depended primarily on a lesion of the central (cortical) representatives of the visual analyzer.

At the same time he succeeded in establishing that the function of the cone cells was impaired much earlier, more thoroughly and more persistently than that of the bacillary layer. This fitted his evolutionary theory, since the older of the two photosensitive-cell systems was the bacillary apparatus of the retina, whereas the cones, performing the function of color discrimination, were a much later acquisition of the animal kingdom and precise distinction of colors was an attribute of man alone. In other words, Strel'tsov regarded the photodiscriminatory function of the eye as a photopathic sensibility and the color discriminatory function as an epicritic sensibility.

This classification indicates that Strel'tsov had adopted, without any reservation, Head's doctrine of two classes of sensibilities, one phylogenetically older than the other (protopathic and epicritic, respectively). His acceptance of this forced Strel'tsov to start a series of investigations on variations of the cuticular, vibratory and gustatory sensibilities at altitude. He himself investigated variations in the sensitivity to temperature and pain (Strel'tsov, 1938c), Samter (1939e) studied the vibratory sensibility and Solovei (1939) the gustatory sensibility. There are indications (Samter, 1939d) that B. V. Tolokonnikov was engaged in research on variations in the olfaction.

These researches showed that the threshold sensitivity to cold and heat rises with altitude and that a man gradually loses the capacity to distinguish slight variations of temperature. At the same time algesia became so acute that at 5000-6000 m the prick of a needle was "quite unbearable". On the other hand, experiment showed that disturbance of the gustatory and vibratory sensibilities occurred only at very high altitudes (above 6000 m).

All these investigations convinced Strel'tsov that: "As anoxemia develops, a dissociation of the protopathic and the epicritic sensibilities is produced. The epicritic sensibility, being phylogenetically younger, gradually disappears altogether, giving way to a protopathic sensibility in no way connected with it" (Strel'tsov, 1938c).

Today, when we can objectively assess variations in the different kinds of sensibility under conditions of anoxia, it must be acknowledged that Strel'tsov, in his enthusiasm for Head's doctrine, which in some sense supplemented his own evolutionary-physiological ideas, drew his conclusions rather hastily, for later research showed that the sensibility disorders suffered at altitude were not strictly in line with the basic theory of propositions of epicritic and protopathic sensibilities. The reason was that hitherto there had been no sufficiently impressive comparative physiological data to support Head's basic proposition that the protopathic sensibility is phylogenetically the older.

It must nevertheless be admitted that Strel'tsov's and his coworkers' research variations in sensibility were of very great interest: the questions posed were novel and a wealth of experimental material was collected.

In studying the reactions of the various receptor systems to anoxia Strel'tsov paid special attention to the function of the vestibular nerve receptors. He was the first to use chronaximetry to investigate this. Nechayev's experiments in this direction (1938a), on rabbits raised to 8000-10,000 m the pressure chamber, showed that the chronaxy distinctly increased at altitude. This indicated a large drop in the excitability of the vestibular apparatus.

Not content with the chronaximetric technique, Strel'tsov decided to try and evaluate the excitability of the vestibular apparatus in terms of yet another index, the duration of the "reversal of rotation" illusion. This work was performed by Tolokonnikov, whose published results (1937-1939) provide

convincing demonstration that the duration of this illusion is many times greater at a height of 5000–6000 m. This time the indication was that the excitability of the vestibular apparatus increased at altitude.

The two methods thus gave contradictory results. Unfortunately, the contradiction seems to have remained unresolved in the Laboratory to this day, for Samter, in his 1949 report, confined himself to citing the results both of Nechayev and of Tolokonnikov's experiments.

Apart from a wide range of research on the reactions of the central nervous system to anoxia, Strel'tsov was attracted to other physiological problems too, particularly the acid-alkali balance. He started researching in this direction, jointly with Timofeeva, back in 1933 and the work was continued in the Laboratory by N. R. Gartvan.

Research on the acid-alkali balance was of interest because in other countries, and to some extent in the Soviet Union (Sirotinin and Timofeeva, 1933), two mutually exclusive theories had appeared in the literature. One school, mainly European, maintained that acidosis developed at altitude; the Americans maintained that alkalosis developed. These contradictory views, based mainly on high-mountain ascents, inevitably attracted the attention of Strel'tsov, who had devoted much effort to getting more precise data on shifts in the acid-alkali balance at altitude.

The very first investigations by Strel'tsov and Timofeeva (1932–1933) had shown that the constant ratio between free CO_2 and bicarbonates was disturbed at altitude. The kidneys soon took part in restoring this constancy, starting to excrete excess bicarbonates with the urine, with the results that pronounced carbonuria developed. The loss of bicarbonates entailed a lowering of the blood-alkali reserve and with the formation of new acid products this could create the prerequisites for a shift of the blood reaction in the acid direction.

Such were the findings obtained in the first stage of the investigations. Later, Gartvan (1938), using potentiometry to investigate the total buffering of the blood, arrived at somewhat unexpected results. It proved impossible to establish any relationship at all between variations in the acid-alkali balance, on the one hand, and altitude or the length of time spent at altitude, on the other; it was found that in man these variations depended on individual characteristics, constitution and condition of the nervous system, that changes in the active reaction of the blood gave extremely varied results and that the total buffering of the blood increased only in severe depression of the central nervous system and showed a tendency to diminish if the CNS was in a state of excitation.

Analyzing these data, Strel'tsov came to the conclusion that under conditions of anoxia some sort of additional buffering substances formed in the blood and helped maintain the blood reaction at constant level. This idea led him to the hypothesis that a factor in regulating the acid-alkali balance was the exchange of chlorine ions between the plasma and the erythrocytes in the

blood itself and exchange of chlorine ions between the blood and the tissues. This hypothesis was perfectly sound, as it was known that any disturbance of the acid-alkali balance always led to changes in the chlorine distribution, particularly if the CO_2 concentration in the blood altered.

The research on chlorine ion concentration in the blood under conditions of reduced atmospheric pressure was performed by V.M. Tarasenko (1939), who found that at altitudes up to 5000 m the concentration increased, but that above 6000 m it sometimes increased, sometimes decreased, quite independently of any peculiarities in the subject's condition at altitude.

The application of biochemical methods of investigation naturally led Strel'tsov to try and trace the metabolic changes, particularly of carbohydrates, induced by altitude. Parfenova's experiments (1938a) showed that a brief period at altitudes between 5000 and 6000 m caused a rise in the blood-sugar level, that a sugar rate of 2.0-2.5 g per kg of weight before ascent produced no glycosuric effects, the sugar being either retained by the liver or undergoing more intensive oxidation. These tests were sufficient indication of more complete carbohydrate utilization under conditions of anoxia. At the same time it was established that the production of sugar prevented the symptoms of anoxia from developing and that additional sugar intake was essential in high-altitude flights.

Looking back over the record, one is struck by the breadth, clear thinking and purposefulness of all the research done by the Laboratory's physiological department and by the fact that the general line of its Director was followed throughout. Strel'tsov adopted a purely Pavlovian method of organizing the scientific research work: everything had to be thrown into working out a single idea, the whole Laboratory had to be subordinated to that idea and no separatist tendencies whatsoever, on the part of individual workers, could be tolerated. Today we can see that during the comparatively brief period of his directorship Strel'tsov did succeed in working out experimentally the problem of anoxia with all the thoroughness it deserved. The experimental data he had obtained over many years were to be the source to which Soviet aviation doctors would turn. Members of the Laboratory staff published forty-two scientific papers on physiological topics alone in the period 1935-1939, apart from the fifteen papers produced by Strel'tsov himself.

Our account of Strel'tsov's work on the physiology of high-altitude flight would be incomplete without a mention of the very considerable contribution he made to the physiology of high-speed flight. This, it is true, was not done in the Laboratory but in the Moscow Institute of Physical Culture, where he was head of the physiology department from 1937 onwards; but an account of his work in this field is in place here, since it belongs to the same period and is representative of Strel'tsov's growth as a creative thinker.

Having accepted Dobrotvorskii's view (1930c) that the center of gravity of subjective and objective disorders due to acceleration lay in "changes in the

conditions of blood flow", Strel'tsov quite logically deduced that the pressoreceptive mechanisms were of prime importance here.

"How, principally, are the accelerational forces which upset the conditions of blood flow in flight opposed and counteracted? In the first instance by the mechanisms regulating the conditions of blood flow", he wrote (1938b). Again, "it is essential to pay attention to the development and training of the physiological mechanisms counteracting accelerational forces".

This led Strel'tsov to realise the need for devising a series of suitable physical exercises, in which the human body would alter its habitual vertical stance, the hydrostatic and hemodynamic conditions would be distrubed and the blood would be displaced, under the law of gravity, from certain parts of the body to others. This led him to stimulate the pressoreceptors, in the first place those of the aortal and sinocarotid reflexogenic zones, and to raise their sensitivity and tone. Such systematic stimulations would train the pressoreceptive mechanisms and greatly increase their efficiency in regulating the blood supply.

The logical next step was to design a tilt table. The Americans "invented" this in 1941; Strel'tsov's coworkers Kudenko and Chirkin, however, were performing experiments with such a table in 1937. The subsequent fate of Strel'tsov's investion was very odd: at a time when the "tilt table test" was firmly established in pilot selection for American and British high-speed aircraft, the Soviet literature did not contain a single paper evaluating the efficiency of this method of investigation.

Once the tilt-table experiments had shown that it was possible to train the regulatory mechanisms of the blood circulation Strel'tsov, jointly with N.A. Bunkin and the team of lecturers at the Moscow Institute of Physical Culture, devised a system of gymnastic exercises in which the position of the trainee's body in space would be altered a great many times and the pressoreceptors would receive systematic, frequently-repeated stimulation. Out of a very large number of such exercises Strel'tsov attributed special importance to loping.

To check the efficiency of this method of training a group of students at the Institute of Physical Culture followed a special course of training for one month. The initial results were very encouraging.

The record shows that Strel'tsov was responsible for devising and introducing into the USSR two methods of physiological training. He had already suggested the pressure chamber and worked out a system for training fliers in it; now he devised a physiological method of improving altitude tolerance. Pressoreceptor training, however, was a physiological technique for improving the flier's resistance to acceleration. Even if Strel'tsov's career had been limited to these two achievements, they are of such historical importance that he would still go down as one of the great pioneers in Soviet aviation medicine.

Strel'tsov formulated all his experimental findings on the physiology of high-altitude and high-speed flight in his doctorate thesis on The influence of reduced barometric pressure and acceleration on the organism (1938). This was the second doctorate thesis (the first was Egorov's) on aviation medicine problems in the USSR. It could be of great value to flight doctors, but, unfortunately, the majority of them do not know it, because it has never been published as a separate title. Strel'tsov was exceptionally versatile. Although he was a pure physiologist he did not confine himself simply to solving physiological problems but was interested in everything that could help ensure optimum conditions for the aviator. As head of the Laboratory he not only refrained from discouraging the hygienists and the clinicians from experimental work on flight medicine; he did everything possible to encourage them.

Reference has already been made to the work done by the Laboratory's otolaryngologists and oculists in trying to discover the effect of anoxia on the sense organs. At the same time, the oculists, mainly Litinskii, put a great deal of effort into problems of practical importance in aircrew examination and in regard to the rational lighting of airfields and the aircraft cabins. One of the experimental problems Litinskii investigated in great detail was that of the flier's depth vision. All this work was described in seven papers which he published in the period 1934-1938.

Equally important were the researches of the clinical therapists Diligenskaya and Filippovich, two of whose works (1933, 1936) were devoted to evaluating the condition of the cardiovascular system in fliers and parachutists. The authors' conclusions was that even in a long tour of duty none of the morbid changes one might expect fliers to suffer because of their unusual working conditions could in fact be detected.

This was an important conclusion, for it was published in 1936 and dictated the Laboratory's theoretical position for several years to come, despite the fact that it had been reached without X-ray or electrocardiographic investigations and based on an inadequate number of test subjects (65 men); most important of all, the factor of natural vocational selection had been left out of account.

Much more interesting was Diligenskaya's experimental investigation (1937) on capillaroscopy, in which he established that in pressure-chamber ascents to 4500-5000 m the capillaries were so drastically restricted that "we were unable to get a blood sample for analysis by pricking Frank's thumb with needle". I myself am still rather unclear about the mechanism of this effect, but Diligenskaya and Strel'tsov believed that the construction of the capillaries was due to intensified secretion of the pituitary hormone.

The work of the Laboratory's psychoneurological department was of exceptional importance in the history of aviation medicine, for the psychoneurologists, like the therapists, advanced a number of fundamental propositions which were to guide the Laboratory in all it future work.

It was a relatively common notion among fliers and some aviation doctors at the time that a flier could "fly himself out", gradually becoming professionally disqualified through progressive decline at his flying aptitude and growing dislike of his work. The Laboratory's psychoneurologists insisted that this was rubbish.

To prove it, Ozeretskovskii, Pisarev and Tereshkovich (1937) made a detailed examination of 167 fliers who had been flying for various (for the most part long) periods. They found no specific manifestations of the "spent" effect in any of them. Admittedly, the investigators did not allow for the factor of natural professional selection, nor did they encounter cases of the pilot's "refusing to continue flying because he had begun to dislike his profession". They did find a relatively high proportion of people suffering from various nervous disorders, but "all these disorders lay within the generally-accepted categories of nervous diseases and are encountered in all professions".

These authors' contention that there is no such thing as a specific neuropsychic disease which could be attributed to the conditions under which a flier works has been supported by a number of aviation psychoneurologists (Subbotnik, 1939b) and is a fundamental postulate of Soviet aviation medicine, diametrically opposed to the views of aviation doctors in other countries. It was confirmed from factual data on the neuropsychic health of Soviet Air Force pilots. Pisarev (1937), on the basis of examinations performed on a thousand fliers, concluded that "we had no complaints on grounds of health and general condition in the majority of the aviators, even after strenuous flying. On the contrary, we found that the personality had developed and that the men were exceptionally efficient." The rest of the psychoneurology department's work was of more narrow practical importance: psychoneurological examination of parachutists (Tereshkovich, 1935), condition of the vegetative nervous system in parachutists with a long record of active service (Tereshkovich, 1936), role of the personal factor in aviation disasters (Pisarev and Tereshkovich, 1937), early diagnosis of epilepsy (Ozeretskovskii, 1937), psychoneurological examination of flying efficiency after an accident Ozeretskovskii and Tereshkovich, 1937).

Nearly all the works of the Laboratory's staff were published in symposia, seven volumes of which were issued in the period 1936-1939 under the general editorship of Strel'tsov, assisted in some cases by Samter and Slonevskii. These symposis are still of exceptional value to every aviation doctor, not only because they crystallize the experience of four years' team work on urgent, topical problems of aviation medicine, but also because they genuinely reflect the exceptionally high level of Soviet research on aviation medicine. The four years of Strel'tsov's directorship were the Laboratory's great days, when the team did its most original work, inspired by the ideas and scientific guidance of Strel'tsov. It was also a period of socialist rivalry between two institutions, both working on the problems of aviation medicine, the Air Force laboratories and the newly-established Institute of Aviation Medicine.

It was natural, therefore, that the Laboratory's work and the problems of aviation medicine should attract the attention of the medical world at large and of the Peoples' Commissariat for Health. In 1937 the Commissariat established a Special Committee, under the Academic Medical Council, on the planning of scientific research in aviation medicine. This Committee got the various scientific research institutes of the Health Commissariat interested in working on aviation topics and, among other things, approved the plan for the All-Union Institute of Experimental Medicine High-Mountain Expeditions. The Committee ceased functioning in 1939.

Another natural development was that the question of recruiting specialists in aviation medicine should be raised. At every convenient moment Strel'tsov would make the point that the training of such specialists was an essential for aviation, that doctors with only a general medical training were not in a position to improve the medical security of high-altitude, high-speed, night and blind flying and that the men responsible for this must possess specialist knowledge. Strel'tsov spent many years demonstrating that the only way to raise the level of qualifications and training of aviation doctors was to provide specialist courses or to rearrange the academic course at one of the medical institutes.

His insistent propaganda led to two historic decisions of the Health Commissariat in 1939: 1) a special department of aviation medicine, headed by Strel'tsov, was established at the Central Institute for Higher Medical Training and 2) an aviation department was opened at the Second Moscow Medical Institute.

THE INSTITUTE OF AVIATION MEDICINE

With the development of Soviet aeronautical engineering in the early 1930s flight altitudes, speeds and distances all increased and at the same time military-aviation training became more and more complicated. The medical service therefore faced a series of intricate, serious and highly-specialized problems.

Some kind of center was needed, where scientific research on aviation medicine could be concentrated in the hands of a well-knit team of scientific and practical workers. Such a center would have to take responsibility for the medical aspects for military aviation, perform an immense amount of research and issue instructions to medical boards on aircrew selection and examination and to field medical officers on aircrew maintenance. Only a specialized institute could perform these functions.

The idea of establishing an institute of aviation medicine was insistently urged by Strel'tsov, until in 1935 the Institute was formed out of Sector IV of the SHRI, under the title Red Army Air Institute of Scientific Health Research.

In 1936 the Institute was renamed as the Pavlov Red Army Institute of Aviation Medicine. It was staffed by the former members of Sector IV, except for Strel'tsov and Apollonov. Dobrotvorskii joined it as assistant head of the Sixth Division. The Institute's first chief was Professor F. G. Krotkov, who was succeeded by I. M. Pruntov, who was in turn succeeded by D. E. Rozenbl'yum.

The new Institute functioned in a building which had once belonged to an out-of-town restaurant called the "Mauritania". The premises were hardly suitable for a scientific research institute but the team fairly quickly reconverted the rooms to their own purposes and started intensive research almost at once. All the necessary laboratories were very rapidly organized, a pressure chamber and a tank for testing temperature and pressure measuring equipment were installed, an excellent library with very good bibliographical material was assembled and the Institute started turning out numerous translations and abstracts on aviation-medicine topics.

It is very difficult to cover now, in a brief account, the whole range and variety of the Institute's work. In the six pre-war years alone it published 148 scientific papers, issued four manuals on aviation medicine and a number of monographs. The record for individual years is as follows:

1936: 21 scientific papers and a number of articles in the book Military hygiene by Krotkov and Galanin.

1937: 13 scientific papers;

1938: 20 scientific papers and a symposium edited by Krotkov, Physiology and hygiene of high-altitude flight:

1939 (the year of the Institute's peak output): manual, Principles of Aviation Medicine, edited by Voyachek; two symposia; two monographs, Noise control in aviation by Borshchevskii and Vestibular training of the aviator by Kulikovskii; 26 scientific articles in various journals;

1940: 13 papers and two monographs: What the flight surgeon must know about blind flying by Popov and Physiological and health security in stratosphere flights by Spasskii;

1941: two new manuals, Aviation medicine and A short course in aviation hygiene; 21 scientific papers.

The prime importance of this vigorous activity was that it represented a breakthrough in Soviet literature for aviation medicine. The aviation doctor could now get a complete picture of the physiological processes occurring during flight and be in a position to give a correct expert opinion on various morbid conditions in a flier. From papers published by members of the Institute staff doctors could see which small points and controversial questions in aviation medicine still required further work, and so these papers themselves stimulated flight surgeons working in the Air Force schools and in field units to do their

own research. This was the period when, under the stimulus provided by the Institute, the country built up the corps of aviation doctors whose work ensured the brilliant victories of Soviet aviators during the Second World War. The Institute's refresher courses, which were very heavily attended by aviation doctors, greatly contributed to this.

The Institute's research work covered almost every essential problem in aviation medicine: the physiology of high-altitude, high-speed, night and blind flight, the problems of stratospheric aviation, aircrew selection and examination for various morbid conditions, hygienic problems. This was a wide range of subjects and the Institute staff manifestly had a profound awareness of the importance, complexity and value of their research.

Some future historian will no doubt give the Institute's story all the attention it merits. My only purpose here is to bring out the principal trend of its activity and show its valuable contribution to Soviet aviation medicine. I shall therefore pass over purely organizational matters and try to describe the Institute's work solely in terms of the 148 scientific papers, manuals and monographs published by the Institute.

1

The Institute published a very large number of papers on the problem of high-altitude flight physiology. In the early days these papers reflected the trend Strel'tsov had inaugurated in the Sector IV days and it was only about 1939 that the Institute developed a completely independent line in this respect.

Much of the research done by Vishnevskii and Tsyrlin, for example, in the period 1936-1938 was devoted to the old problem of the effects of anoxia on the visual function. New experimental data had been obtained in the interval, providing further confirmation of the fact that under anoxia the photosensitivity, sensitivity to color and electrosensitivity were reduced, the area of the blind spot altered, the intraocular pressure altered and depth-perception deteriorated owing to disorders of the ocular muscular apparatus. At the same time new findings showed that photoperception and color perception were affected at 1500 m, that color sensitivity was not fully restored even by oxygen inhalation at altitude but that the electrosensitivity and dark adaptation were fully restored and that anoxia first affected the retinal cone apparatus (Vishnevskii and Tsyrlin, 1936b).

These authors drew an extremely important inference from all these investigations on functional disorders of the visual analyzer at altitude: namely, that the deterioration of vision under conditions of anoxia was due to "the influence of oxygen deficiency on the central representative of the visual analyzer in the cortex" (Vishnevskii and Tsyrlin, 1939a).

The importance of this conclusion was that it added precision to the Soviet view on the course of physiological processes under conditions of hypoxia. While investigators in other countries were dominated by the view that functional disorders of the vision at altitude were due to changes in the photochemical processes in the retina, the Soviet opthalmologists Vishnevskii and Tsyrlin were advancing, for the first time, an idea which fitted in with the special emphasis given by Soviet physiology to the primacy of the cerebral cortex in response to various stimuli.

If the visual analyzer's response to altitude hypoxia was so sensitive, it was only to be expected that other analyzers with cortical representation should also suffer functional deterioration under similar conditions. This raised, in the first place, the question of functional disorders in the acoustic and vestibular analyzers.

Experimental study of this question was undertaken mainly by A. P. Popov and I. Ya. Borshchevskii, and partly by A. A. Pukhal'skii. Popov and Borshchevskii first (1937) set themselves the aim of determining how oxygen deficiency affected the vestibular reactions. Experiments in which the subjects were rocked on swings while breathing first atmospheric air, then a gas mixture containing 12-8% of oxygen, produced no clear-cut indications of impaired vestibular reactions.

Popov's research on the acoustic analyzer (1937a) involved testing 39 subjects breathing a gas mixture containing 10.5-8.7% of oxygen for one hour. Only 10 subjects suffered deterioration of acoustic acuity; no change at all was detected at all in the other 29. Similar investigations by Popov (1938c) in a pressure chamber again produced no definite results. In view of the discrepancy between what ought to happen and what did in fact happen Popov suggested that there was probably a subcortical as well as a cortical representation of the hearing. Depression of the cortical functions under conditions of hypoxia would then entail depression of the cortical representative of the acoustic analyzer; but the depression of the cortex would simultaneously disinhibit the subcortex and the excitation of the subcortical representative would to some extent compensate the depression of the cortical representative. Kulikovskii supported this point of view (1939b).

The variation in the responses of the olfactory analyzer under conditions of hypoxia was investigated by Pukhalskii (1939b). Experiments on 25 subjects in a pressure chamber showed that a 5000-6000 m olfaction deteriorated only in 10 subjects, no change being observed in the other 15.

Pukhal'skii, in a paper submitted to the All-Union Conference on Aviation Medicine in 1939, summarized all this research on the influence of altitude on the otorhinolaryngological organs and concluded that the effect of hypoxia on the functioning of the acoustic and vestibular apparatuses was negligible. Although the vestibular chronaxy rose, no definite pattern could be detected in the reversal-of-rotation reactions, although olfaction was slightly impaired.

Pukhal'skii believed that during high altitude flight the acoustic organ was much more affected by atmospheric-pressure drops than by lack of oxygen.

The effect of hypoxia on the central nervous system was the subject of only one experimental investigation, by Sobennikov (1939b). He investigated in a pressure chamber subjects with a healthy nervous system, subjects with an asthenic syndrome and subjects with disorders of the vegetative nervous system. His conclusion was that at 4500 m subjects with a healthy nervous system suffered "no psychic disorders and no disorders in the reactions of the vegetative nervous system"; these appeared only at an altitude of 5000 m. Reactions of the central nervous system, however, appeared in subjects suffering from the asthenic syndrome at 4500 m; in subjects suffering from disorders of the vegetative nervous system "the altitude ceiling was appreciably lowered".

Despite the very great practical value of this work it was not carried further. Vorontsovskii's research on the renal reactions to reduced atmospheric pressure (1941a) have the same somewhat isolated character. Vorontsovskii concluded that under low-temperature conditions at altitude the diuretic reaction varied from one individual to another. In cases where the compensatory mobilization of the regulatory mechanisms was complete, hypoxemia appeared to elicit no significant diuresis; but when the hypoxemia compensation was prevented for one reason or another, oliguria set in. The author thought this might be a symptom of reduced altitude tolerance.

Another isolated piece of research was Skrypin's work (1941) on analysis of the blood gases and the acid-alkali balance resulting from the repeated effect of short periods of reduced atmospheric pressure. He found that one hour's flight at 5000 m caused a shift in the direction of gaseous alkalosis but that compensatory mechanisms prevented the blood pH from suffering any alteration whatsoever.

All these experimental investigations by Sobennikov, Vorontsovskaya and Skrypin would have been immensely valuable had they been carried further; unfortunately, they were not, perhaps because, as it happened, we were on the eve of war.

Apollonov, on the other hand, on joining the Institute, in an honorary capacity, shortly after leaving the Central Psychophysiological Laboratory, managed to continue the research on the respiratory actions at altitude which he had started there. He published comparatively few reports on experimental research, only four in all, partly in conjunction with Mirol'yubov. These concerned the problems of oxygen supply when resting and when working at various altitudes (Apollonov and Mirolyubov 1937), quantitative variations in the hemoglobin level and the urine pH after 1.5 - 3 hours flight at 4800-5800 m and evaluation of the CO_2 increment to breathing oxygen at altitude (Apollonov and Mirolyubov 1938a and b). In these papers Apollonov proved that up to 1100 m

the oxygen demand did not alter either when rest or when working, that inspiration of pure oxygen enabled even intensive work to be performed at altitudes up to 11,000 m and that there were no grounds whatsoever for adding a small percentage of CO_2 to the breathing oxygen at altitude.

Detailed study of the respiratory process at reduced atmospheric pressure and prolonged experimental work in this field enabled Apollonov to write the main chapters in manuals published by the Institute (the chapter on Pulmonary respiration at altitude in Principles of aviation medicine, 1939 and the chapter on Respiration at altitude in Aviation medicine, 1941). The only defect of these chapters, which are based on a profound knowledge of the subject and are written in excellent literary style, is that the author makes too little reference to his own research or to that of Soviet aviation. The latter criticism, incidentally, applies to all the other contributors to these manuals.

In addition, Apollonov continued his detailed study of apparatuses. This work had an application to aviation. Apollonov, an unsurpassed expert on the subject, had a thorough knowledge of an immense number of oxygen apparatuses. His chapters on Oxygen supply in high-altitude flight and oxygen apparatus in Aviation medicine (1941) and An oxygen respiratory apparatus for high-altitude flights in A short course on aviation hygiene (1941) could have been written only by an author of profound erudition.

A considerable part of the research done by the Institute was devoted to the problem of pressure-chamber training. The pressure chamber was still a novelty for field medical officers, who knew little about its structure or the techniques of using it; so there was every justification for the two detailed descriptive articles by Mirolyubov (1936a and b), explaining the techniques of using the device and for another article by Isakov (1941) on the problem of varying the pressure regime in working with it. But the key question, on which Strel'tsov had long been insisting, was that of improving hypoxia tolerance by pressure-chamber training. This called for sustained, systematic experimental study. That altitude acclimatization was a possibility had long ago been established in principle, through the experience of high-mountain ascents; but the question now was whether compensatory mechanisms could be mobilized by brief but systematic "ascents" in the pressure chamber. From first to last the Institute steadfastly maintained that such training was possible, useful and advisable.

Fainberg, in his very first work on this question (1937), had noted that after twelve ascents to 5000-7000 m, each lasting from 30 to 120 minutes, acclimatization shifts could be detected in the red blood and were retained in the organism for 18-25 days after the last ascent. He therefore concluded that pressure-chamber training was a potent method of improving altitude tolerance.

One year later Fainberg and Bizyaev (1938) verified that acclimatization adaptations could be elaborated by breathing oxygen-impoverished gas mixtures at ground level. They concluded that this method would improve altitude

tolerance, since the oxygen capacity of the blood, in this case, would increase. The most effective gas mixture was one containing 11.0% of oxygen. The acclimatization effect lasted for 12-15 days.

The basic propositions of these works reappeared in the paper on Improving the organism's tolerance to high-altitude flights by Gurvich and Fainberg in the book Physiology and hygiene of high-altitude flight (1938). Mirolyubov based his section, Pressure-chamber training in the book Principles of aviation medicine (1939) on the same data and it seems that they were in fact the basis for the training system actually introduced.

By 1938 then, the advisability of pressure-chamber training had been finally accepted in the Institute. The method was recognized as an essential element in training aviators for high-altitude flight and as such was incorporated in the official instructions. A unified training system was devised, consisting of 5-7 ascents, lasting 30-60 minutes, to 5000-5500 m at a speed of 8-10 m/s, followed by a landing of 10-15 m/s. Air Force units were henceforth to be equipped with pressure chambers and flight surgeons were required to use them for systematic aircrew training, according to a fixed schedule; for the next three years this was one of the main duties required of them.

Later, Skrypin (1941), on the basis of new research on the blood reactions, again confirmed the advisability of pressure-chamber training. In his opinion, the more altitude ascents in the pressure chamber, the better; the average must be 10 to 12 and the intervals between ascents should not exceed 4 days; the training altitude should be 5000 m and the trainee should remain at this altitude for one hour. Under these conditions the acclimatization shifts, according to Skrypin's data, were retained in the organism for 2-3 weeks.

In 1940 a large unit, consisting of Gerasimova, Isakov, Kuznetsov, Milyagin, Rosenbl'yum and Skrypin, was created to investigate more fully the processes of altitude adaptation through pressure-chamber training. This unit reported to the first session of the Moscow Society of Physiologists (1941) and its findings were reflected in a paper by Rozenbl'yum on Improving the organism's tolerance to high-altitude flights in the book Aviation medicine (1941). The special contribution of this team was radically to alter current views on the essence of altitude acclimatization. Whereas Fainberg and, to some extent, Skrypin, had regarded alterations in the red blood as the basis of altitude adaptation thus attributing the main role to hemoglobin, the team adopted a somewhat different standpoint. It established that as a result of systematic pressure chamber "ascents" to 5000 m, a series of regulatory mechanisms came into play, with the result that "coordination and efficiency of the oxygen-deficit compensating reactions improved". A number of new facts were discovered in the process of training. It was established, for example, that the partial pressure of oxygen in the alveolar air increased from ascent to ascent, that the oxygen level in the arterial blood rose, that gaseous alkalosis was almost entirely compensated, that the blood reaction remained within normal limits because the bicarbonate level in the blood was reduced, that the quickening

of the pulse became less pronounced, that the respiratory rhythm was normalized and that the photosensitivity of the eyes improved. No uniform characteristic variations in morphological composition of the blood were established. In particular, in regard to polyglobulism, it was established that the erythrocyte count increased, primarily due to erythrocyte leaching from the blood depots, while true erythrocytosis appeared only in a mild, inconstant form, the erythrocyte count returning to normal after 1 to 3 hours. But a specially important conclusion was that "the length of time during which the detectable signs of adaptation to altitude are retained is 1 to 1-1/2 months" (Rozenbl'ȳum, 1914b).

These findings definitively established the Soviet point of view on the fundamental advisability of pressure-chamber training for fliers and on the potentiality of this method for improving altitude tolerance; Strel'tsov's idea that many of the fliers' physiological functions could be trained was thus vindicated.

2

The Institute's work on high-speed flight was much less impressive. This was entirely due to the technical difficulties of studying the influence of accelerations on the human organism. For the study of hypoxic effects the Institute had at its disposal the pressure chamber, the temperature-and-pressure tank, the rebreather and the Egorov and Aleksandrov instruments; but for experimental work on accelerational effects it had no equipment at all. The investigators had to be content with observing and interrogating pilots performing various high-speed aerial maneuvers and with carrying out simple medical examinations. The lack of thorough experimental work meant that the scientific papers produced by the Institute's staff on this question were almost exclusively of a review character.

The only field in which experimental equipment was available was that of the vestibular responses to various forms of acceleration. A great deal of work was done in this direction by Popov, who relied on the basic propositions of the Voyachek school.

With this year-by-year improvement in Soviet aeronautical engineering, however, the Institute found itself seriously faced with the problem of accelerational effects on the flier and the team did everything in its power to tackle this problem. They assiduously read everything published on the subject, made a detailed study of the mechanisms by which inertia forces were generated during the performance of various aerobatics, constantly consulted designers, engineers and fliers and worked out certain ideas on the influence of acceleration on the organism. The starting point for these ideas was Dobrotnorskii's proposition to the effect that changes in the hydrostatics and hemodynamics were inevitable under conditions of acceleration. These ideas were reflected in

review articles by Gurvich and Mirolyubov (1936) and in various papers by Rozenbl'yum (The influence of acceleration on the cardiovascular system in Principles of aviation medicine, 1939 in the paper read at the All-Union Conference on Aviation Medicine in the same year and in the article on The influence of acceleration on the organism in the manual Aviation medicine, 1941). In all these works Rozenbl'yum showed profound theoretical knowledge of the problems involved and there can be no doubt that if the Institute had been in a position to do experimental work on this question it would have produced its own point of view on it and proposals for improving acceleration tolerance.

As things were, however, they had to be content with interviews on the flying field and with analyzing the subjective sensations of the aviator and performing elementary medical examinations. A team consisting of Borshchevskii, Mirolyubov, Rozenbl'yum, Sobennikov, Turov and Tsyrlin had been created for this purpose in 1938. On the basis of its observations this team concluded that a load of 6.0 g lasting for one second had no effect on the pilot's performance and gave rise to no subjective complaints, but that at 7.0-8.0 g two out of five fliers blacked out, while fresh erythrocytes and granular cylinders appeared in the urine (Borshchevskii et al., 1938).

These conclusions were not fully borne out by subsequent experimental research. The tolerance thresholds mentioned above were found to be somewhat exaggerated; from the subsequent observations, however, members of the Institute staff reached the conclusion that a flier's ability to withstand acceleration was a good deal higher than had been experimentally established by investigators in other countries. A second team, consisting of Popov, Samukhin and Belostotskii, studied the "zones of acceleration-tolerance at high altitude" (Popov et al., 1940) and concluded that at 4500-5000 m the flier could withstand brief accelerations up to 9.45 g. They had to admit that some fliers suffered temporary blackout at 4.0 g but they believed this to be an occasional effect, depending on some individual characteristics. Acceleration caused no persistent physiological changes. In his last work of this character (1941a), based on careful observation of fliers engaged in dive bombing, Popov concluded that the pilot rarely suffered acceleration greater than 4.0-4.5 g on emerging from the dive. He found that acceleration tolerance was much more affected by the day's routine, by fatigue, by the pilot's having slept badly the night before and so forth and he recommended raising the requirements in regard to the neurosomatic and particularly the emotiovegetative condition of aircrew personnel at the periodic medical examination.

His research on this problem directed Popov's attention to experimental study of the effect of accelerations on the vestibular apparatus, which had long been known as the "organ of accelerational sensation". He published his results in a series of papers, including The Influence of Coriolis forces, acting on the human labyrinth, on the blood pressure (1938d), The effect of accelerations on the vestibular apparatus (1938c), The influence of labyrinth-generated Coriolis accelerations on the human organism (1939i). Two works by Kulikovskii in Principles of Aviation medicine (1939) and Aviation medicine (1941) belong to this category.

In his experimental work Popov aimed primarily at establishing the acceleration thresholds. He found that these were subject to much individual fluctuation, but established the following average values: vertigo threshold - angular $1.3^{o}/s^{2}$ for 20 seconds; threshold for sensation of retardation of rotatory motion - $1.14^{o}/s^{2}$ positive acceleration for 8.5 seconds; rectilinear motion threshold - acceleration of 9.8 cm/s^{2}; centrifugal force starts to be felt at 0.05-0.02 g. At the same time Popov verified from his own experiments Schubert's contention that the generation of Coriolis accelerations during radial accelerations caused a reflex fall in the blood pressure. Experiments showed that Coriolis accelerations generated in the labyrinth, even at such high radial accelerations as 4.0 g operating for 10 seconds, did not cause any disturbance sufficiently important to upset efficiency and orientation.

All this shows that the Institute's team did everything it could to make a serious experimental study of accelerational effects and that the only reason it was unable to contribute towards solving the problem was its total lack of the necessary equipment.

3

The physiological problems of high-altitude and high-speed flight involved many members of the Institute's staff and even the organization of special teams. The problems of stratospheric flight, however, engaged only one of the Institute's departments, headed by V.A. Spasskii.* It is hard to see the reason for this isolation. I have gone through the literature for the period 1938 to 1941 without finding a single paper by members of other departments on aircrew protection in stratospheric flight. The single article by Krotkov on The high-altitude flying suit in the book Physiology and hygiene of high-altitude flight (1938) is no exception, since it really consists of nothing more than a description of flying suits designed in other countries.

Spasskii himself published a wealth of material, based on prolonged experimental work, in a number of papers which appeared in 1938 and 1939, in chapters on the physiological and health protection of air crews in

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*A.A. Pereskokov had started working in this direction even before Spasskii. He was one of the designers of the first Soviet stratospheric flying suit. After the publication of his paper Air-crew protection in stratospheric flight in Military hygiene by Krotkov and Galanin (1936) he for some reason gave up this work.

stratospheric flight in the books Principles of aviation medicine (1939) and Aviation medicine (1941) and, especially, in his doctorate thesis, published as a monograph under the title Physiological-health protection of air crew in the stratosphere (1940). In these works which indicate that he was well acquainted with the literature on stratosphere flight, he drew extensively on the experience of the Moscow and Leningrad physiological teams working on the stratospheric balloon project and made use of his own wide experience in testing the Soviet flying suits designed by Pereskokov and Rappoport (the GVF), Chertovskii (the CH 3) and Khromushkin and Boiko (the TsAGI).

Spasskii's principal conclusions amount to the following. Partial pressure of oxygen in the air inhaled in stratosphere suits must not be less than 125 mm Hg, corresponding to flight conditions at 2000 m altitude. Elimination of CO_2 and water vapors from the air of stratospheric suits can be effected either by air renewal or by ventilation. Spasskii regarded the latter as the simpler and more reliable method. A 15-mm Hg rise in the partial pressure of CO_2, corresponding to a CO_2 level of 2% in the air at a pressure of 760 mm, was permissible. Spasskii suggested taking 20, 25 and 30-50 liters as the standard CO_2 evolution per man per hour in the gondola of a stratosphere balloon, the cabin of an aircraft and a flying suit, respectively; air temperature within a stratospheric machine should be kept preferably within the limits +16 to +18°C, but Spasskii did not think it possible to formulate categorical requirements in this respect. The regulation of air humidity proved difficult. Spasskii regarded 40-60% relative humidity as the ideal but a temporary rise to 85% as permissible. Humidity calculations must be based on the assumption that at a temperature of 15°C water evaporation from the skin surface and the lungs was 50 g per man per hour. Standard air exchange in a stratospheric machine should be not less than 50 liters per man per minute.

Spasskii's research led him to the conclusion that physiological health and comfort could be completely assured in stratospheric flight provided the cabin was hermetically sealed. He did not, however, indicate precisely what type of sealed cabin was the most suitable, the regeneration or the compressor-ventilation type. The advantages of special suits were limited, for they could not be as comfortable as cabins. All these conclusions were subsequently revised, but at the time they appeared in print Spasskii's papers and his demand for sealed cabins and special flying suits were original and completely new in Soviet aviation medicine. Moreover, his work shows that the Institute reacted promptly to every new idea developed by the nation's aeronautical designers and was always ready to direct its workers to any new problems affecting the future of Soviet aviation.

4

Three members of the Institute, Vishnevskii, Belostotskii and Tsyrlin, were concerned with the physiology of night flying. Vishnevskii had started working on these questions while he was still at the Central Psychophysiological Laboratory and he had continued with it in Sector IV and at the Institute of Aviation Medicine for almost the whole period of the latter's existence. His closest associates, Tsyrlin and Belostotskii, greatly helped him with the experimental research and in solving a number of practical problems. In the period 1936-1940 these authors performed a series of experimental investigations on the ocular functions under conditions of poor illumination.

Even in his first work of that period, published under the title Night flying in the book Military hygiene (Krotkov and Galanin, 1936), Vishnevskii had used a number of valuable data on the peculiarities of night vision and given fliers much important advice. He had established, for example, that at a brightness of less than 0.2 microstilb only the bacillary apparatus of the retina functioned, that at brightnesses between 0.2 and 230 microstilbs both the bacillary and the cone layers functioned and that above 230 microstilbs only the cone layers functioned. Vision deteriorated so much, under conditions of poor illumination, that the time taken to distinguish poorly-illuminated objects was often measured in seconds. The author recommended that only fliers with normal acute vision, normal color perception and normal dark adaptation should be selected for night flying. He regarded it as essential that the artificial illumination of the quarters in which the men spent their time before a flight should be uniform and without excessive contrasts or excessive brilliance, and that all direct sources of light should be concealed from the eyes. Further, he recommended that before a night take-off the pilot should accustom himself to the prevailing illumination by staying on the airfield for not less than 10-15 minutes. Night vision would be improved by inhaling oxygen at altitudes above 1500 m; the lighting installations in the cabin must be such as to enable the pilot rapidly to alter both the degree of illumination and the color index; and the use of light-filter goggles should not be allowed in night flights.

These recommendations were expanded and developed in later works. In 1937 Il'ina published a detailed investigation on vision under conditions of poor illumination and concluded that the identification of details depended not only on the degree of illumination but also on the color index: differentiation of details was poorest under blue light and best under red. In 1938 Belostotskii constructed a special instrument for determining acuity of vision under conditions of poor illumination. In 1939 Batenko, in determining the field of vision under conditions of poor illumination, found that it narrowed as illumination of the perimeter arc was reduced; this effect set in at 0.2 lux and became more pronounced at 0.1 and 0.05 lux. In the same year Vishnevskii and Tsyrlin (1939a), determining the sensitivity threshold for constant color flares against a white background under conditions of poor illumination, found that both the light and the color thresholds varied not only from one individual to another but

also in the same individual, the fluctuations being greatest in regard to green and blue flares. At the same time Belostotskii (1939b) showed that at brightnesses of less than 25 microstilbs pronounced deterioration of the central vision set in, that at brightnesses of 25-30 microstilbs the central visual functions were maintained at fairly high altitudes but the light sensitivity was slightly reduced. In 1940 Vishnevskii and Kravkov designed an instrument for studying night vision. Belostotskii tested this and found it completely satisfactory. The Institute was thus obviously on the right path in regard to the physiological problem of night flying.

5

Another subject which attracted the Institute's attention was blind flying. Here Popov took the lead. In a series of articles published in 1936-1940 and mainly in his monograph What the flight surgeon must know about blind flying (1940), he expounded all the basic principles and instructions necessary for training pilots for blind flying. In this he not only drew on all past experience of such training and made a systematic experimental study of the question, but also personally made a series of night flights.

Popov placed the main emphasis on investigating the functions of the vestibular apparatus and the reflex effects deriving from it. Observations showed that although the same stimuli acted on the vestibular apparatus during blind flying as during ordinary flying, the vegetative reflexes (pallor, vertigo, nausea, vomiting and other symptoms of air sickness) were more frequent and sometimes more pronounced in blind flying. The reason was that the flier's possibility of orientating himself by sight was greatly reduced. Stimulation of the visual analysor seemed to inhibit the vestibular reflexes. Experimental observations showed further that on the swings unpleasant sensations occurred more often if the eyes were closed than if they were kept open. Flying with bandaged eyes in aircraft gliders convinced Popov that it was impossible to determine changes in the position of an aircraft (banking turns, long turns, slow ascents and descents) from one's own sensations. He concluded that "the pilot's instruments for orientating the aircraft in space are more accurate than the human vestibular sensation" and that instructors were quite right to forbid their students to make any corrections to the instrument readings based on their own sensations.

These conclusions provided an experimental basis for the empirical instructions on blind-flying training which had been in force up to that time. On the other hand, the author's conclusions that "it is impossible to determine the position of an aircraft by means of the vestibular apparatus or any of the other proprioceptors if vision is cut out" finally disposed of the views of most foreign and some Soviet investigators who believed that the vestibular apparatus played an important part in the creation of a "flying sense" and that it acted as a sort of physiological compass for the pilot.

It is clear from all this that the important thing in training a pilot for blind flying must be to instill habits of distrusting the subjective sensations produced by the other analyzors when vision is excluded and great confidence in the instrument readings.

6

The physiology of the vestibular apparatus persistently attracted the attention of the Institute's workers and here they reaped the full benefit of the attention paid to this question at the dawn of aviation. The problem of training the vestibular apparatus remained particularly acute in the Institute for a number of years and stimulated a series of investigations by Popov, Borshchevskii and Kulikovskii. In several papers published by these authors in 1936-1940 and particularly in Kulikovskii's monograph Vestibular training of the pilot (1939a) the necessity and unequivocal usefulness of this form of training was urged. Khilov swings, the Báránŷi chair, loping and a number of other physical exercises were suggested for this purpose. Kulikovskii even insisted that "the entire course of physical training should be saturated with exercises specifically designed to train the vestibular apparatus".

It is obvious that to some extent these authors had not derived their conclusions from factual observations. Their preconceived idea on the usefulness and effectiveness of vestibular training usually prevented them from evaluating observation results objectively and getting rid of contradictions. Borshchevskii for example (1938c), in experimental comparative evaluation of different swings for vestibular training, concluded that simple swings were more effective than the Khilov type, yet Kulikovskii persisted in recommending the latter. Popov (1939) demonstrated the effectiveness of the Link trainer but his figures in support of this recommendation were unconvincing. In 1936 the proportion of Link-trained pilots to acquire excellent blind-flying technique was 60 per cent, compared with 34 per cent good and 5 per cent average; the corresponding figures for pilots not so trained were 32 per cent, 51 per cent and 16 per cent. In 1937 roughly similar figures were obtained. The difference between these figures is not so remarkable as to provide convincing evidence of the efficacy of the training. Kulikovskii found that "mass tests (of fliers? - A. S.) established that 40.3 per cent required training of the vestibular apparatus" (!) and reached the paradoxical and false conclusion that passive training was more effective than active training.

Despite the Institute's failure to demonstrate the efficacy of vestibular training, the necessity for it was still insistently advocated. The Institute itself obviously upheld this point of view, for in 1941 Kulikovskii, in his chapter on vestibular training in the book Aviation medicine, repeated the same erroneous views that he had advanced in his monograph.

At first sight it seems that this insistence on introducing vestibular training arose from the anxiety to obtain effective prophylaxis against air sickness and that the Institute was in fact concerned with that problem. This is quite untrue. There is no evidence in their work that the members of the Institute were at all seriously interested in air sickness. Kulikovskii's chapter on it in Principles of aviation medicine, 1939 deals with the etiology, pathogenesis and clinical picture of the disease quite superficially. That the Institute was not particularly interested in the matter is clear from the book Aviation medicine alone: this came out two years later but Kulikovskii simply reproduced his former article, hardly altering anything.

Nor did anyone else in the Institute make any detailed study of air sickness. Admittedly, Borshchevskii in 1937 tested the effectiveness of aerone as a prophylactic but reached negative conclusions. Two years later (1939e) he repeated the same conclusions in a second work and said that the problem could not be solved. In 1940 he tried a new preparation consisting of belladonna and strychnine on 20 subjects suffering from hypervagotonia and obtained good results in 13 of them. In 1939, however, Kulikovskii was distrustful of all pharmacological preparations and in 1941 he does not mention them at all.

The problem of air sickness was obviously not sufficiently acute for the Institute to bother about and they did very little work on it. In the circumstances, it is hard to see why the otolaryngologists at the Institute spent so much effort advocating and introducing vestibular training as a prophylaxis against air sickness.

7

Another problem which the Institute tackled in a very vague and indeterminate manner was the effect of his job on the flier's organism. The Institute did hardly any work on this, although it had ample opportunity. Quite apart from its own clinical department, the Institute had at its disposal all field unit flight surgeons and flying school medical satff and could have devised a procedure for making extensive use of the annual medical reports and unit medical officers' routine observations of aircrew personnel. It is a great pity that all this material remained unused and that of all the people working at the Institute not one took up this subject.

Instead of a broad plan we find only very tentative attempts by individual workers to study the effect of his job on the flier's organism. Mirolyubov took the lead, with an article on The influence of flying duties on the cardiovascular system in the sedate journal Clinical medicine. On the basis of a detailed study of 137 pilots and the autopsy reports on 48, and by comparing the results with the length of service, the author concluded that the number of fliers with a healthy cardiovascular system progressively diminished with the length of

service: 34.3 per cent had completed five years' service, 13.1 per cent up to ten years, 11 per cent up to thirteen years, 9.5 per cent up to sixteen years and 2.2 per cent up to nineteen years. Comparison of the pathological data with the number of flying hours revealed a similar picture and no one at all was found to have a healthy cardiovascular system after 3000 flying hours. The author concluded that the strain of flying played the dominant part in producing changes in the cardiovascular system, the most characteristic being an increase in the incidence of cardiac hypertrophy.

It is impossible to find any indications whatsoever, either in individual papers or in the manuals issued by the Institute in later years, to show whether Mirolyubov's conclusions were confirmed or not. The only hint is in a paper by Vorontsovskaya published in 1941, in which he concludes, on the basis of studying 75 cases of cardiovascular disease in fliers treated at the Institute, that none of the diseases detected could be regarded as pathogenetically connected with the job.

These two diametrically opposed and mutually exclusive conclusions remained unreconciled throughout the eight years of the Institute's existence and no one on its staff took up the subject*.

Another matter which for a long time engaged Borshchevskii's attention was the effect of aircraft noise on the flier's hearing. Even in his early work on the influence of noise Borshchevskii (1938a and others) had said that flying must be classified as a "noisy profession" and that the impaired hearing observable in some fliers could be due to acoustic trauma. In 1939 he was already definitely of the opinion that "repeated hearing tests on aircrews indicate that their hearing is gradually impaired"; he fully assumes the traumatic effect of aircraft noise on the flier's hearing organ and said that "if we want our aviators to keep their hearing, the high command and the medical authorities must face the problem of protecting it" (Borshchevskii, 1939d). In 1941 he again stated that aircraft noise within the range 110-118 db predisposed the flier to impairment of the hearing.

One might have expected the Institute to react to these insistent pleas by one of its leading members and to demand that impairment of a flier's hearing be officially recognized as an occupational disease; one might have expected it to issue instructions to the numerous medical boards to the effect that if a flier was grounded for defective hearing his certificate should show that the defect was of occupational origin. Nothing of the kind: Borshchevskii's conclusions remained his private opinion and no one else was in the least bound by them. Proof of this can be found in chapter 18 of <u>Aviation medicine</u> (1941), written by Kulikovskii, in

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*There are indications that Mirolyubov's work provoked extensive discussion within the Institute and that his conclusions were rejected; but no records of this discussion, which would have widely interested aviation doctors, was published.

which there is not a word on the adverse effect of aircraft noise and Borshchevskii's research is passed over in complete silence.

8

The Institute did basic work on the problems of aviation hygiene: rationalizing the clothing and feeding of the flier, protecting his organs of vision and hearing, prophylaxis against poisoning by aviation fuel and a number of other questions.

Under the direction of P. E. Kalmykov much work went into the search for suitable flying clothing. Various types of flying suit were designed and tested not only in the aerodynamic tube and temperature-pressure tank at -34°C but also under conditions of prolonged high-altitude flight. As a result several types of flying suit were suggested. Some were taken into service and approving testimonials were received from fliers. Footwear, gloves, helmets and masks were studied with equal thoroughness and the Institute made suggestions for improving their efficiency, based on experimental verification and trial. Electrically-heated clothing was the one subject which the Institute did not deal with adequately.

A great deal was done also, particularly by P. M. Batenko, to improve goggles. Triplex, plexiglass and securite were subjected to detailed investigation in regard both to transparency and shape of lens. Much experimental work was done to find the most suitable light filters and the Institute designed a new yellowish-green filter. Much work was also required in order to design the most suitable frame. The curved shape of the frames made it necessary to determine the field of vision and the acuity of the depth vision. A great deal of effort went into devising ways of overcoming steaming-up of the goggles.

Much work was done too on designing various types of anti-noise equipment. Even though the adverse effect of aircraft noise on the flier's hearing had not been really clarified at the Institute, nearly all the otolaryngologists on its staff did make improvements to the design of noise-attenuating devices (the Kalmykov, Akopdzhanyan and Klimovitskii ear plugs, the Parfenov anti-noise helmit liner, the Kulikovskii ear-muff, the Popov all-purpose helmet and so forth). The person mainly responsible for testing all these devices was Borshchevskii, who did an immense amount of experimental work, described in a series of papers published in 1936-1941 and in his monograph Anti-noise devices in aviation (1939f).

The Institute also did a great deal of work on the food question. As early as 1936 Andreev and Trofimuk had worked out detailed menus for six types of meal; Kornev and Trofimuk designed an electric flying thermos flask. During the same period the Institute worked out standard diets for aircrews. In papers published in 1937 and 1938 Kholin examined in detail the standard diets introduced

in 1936. These laid down a ration of 118 g of proteins, 117 g of fats and 480 g of carbohydrates, with a total calorie value of 3434, for the midday and evening meals alone. The calorie value of the trainee ration was 4145. At the same time a flying ration of 1565 calories for use during flights lasting more than six hours was introduced, together with emergency rations for forced landings (3052 calories). In 1939 Arutyunov and Kholin again worked out numerous lunch and supper menus. In addition, they devised a diet for high-altitude, night and long flights and new flying and emergency rations (Arutyunov and Kholin, 1939a). In 1940 Arutyunov worked out a new high-altitude flying ration to be used during high-altitude flights lasting seven to twelve hours. At the same time he and Petrov invented a special container to prevent the flying ration from freezing.

The Institute thus showed itself energetic and persistent in its efforts to improve aircrew diet. But if one asks what all these standards were based on and whether any experimental work was done to determine the flier's energy expenditure one cannot find any record of research on this matter in all the institute's numerous transactions. In 1939 Arutyunov and Kholin wrote: "We still lack scientifically sound data on the physiological and health aspects of diet for professional fliers, but work has already been started on many of these problems" (Arutyunov and Kholin, 1939a). I can find no evidence in the Institute's publications showing that this promise was fulfilled.

The list of matters on which the Institute worked does not cover all aspects of aviation hygiene, but it does show that the subject formed an integral part of aviation medicine.

9

Aircrew selection and examination accounted for an exceptionally large part of the Institute's work. This was to be expected. As experience accumulated, views on various aspects of selection inevitably changed; so too did the methods of examination as the demands made on the flier's organism in regard to pathological disorders became more precisely defined. All this called for validation and discussion. In the period 1937-1941 32 papers on these subjects were published by members of the Institute, a joint paper on the selection of candidates and the examination of aircrew was published in Principles of aviation medicine, another large joint paper, on Aeromedical examination, appeared in the book Aviation medicine and in 1939 a special Manual for Red Army Air Force medical boards was published.

Nearly all members of the Institute took part in this immense work, but the main authors were Belostotskii, Borschevskii, Vishnevskii, Kulikovskii, Mirolyubov, Popov, Samukhin, Sobennikov and Subbotnik. The long quest for reliable selection and examination methods finally enabled the Institute to bring out its own doctrine of aircrew medical examination, an exceptional achievement on

the part of Soviet aviation medicine. The hallmark of this doctrine is the absolute repudiation of psychotechnical and psychophysiological methods of examination, which are replaced by a well thought-out technique of thorough clinical examination and individual evaluation of particular disorders, in which the special demands imposed by the responsibility of command are also taken into account.

10

All the above problems were fundamental to the Institute's work; but in addition, many minor problems engaged the attention of its individual members. The Institute as a whole, for example, was little interested in the effect of pressure drops on the organism and its manuals contain no information on this. The only published paper, by Mirol'yubov (1941), merely gives a few data for general guidance. On the other hand, the effect of pressure drops on the cavity of the middle ear was the subject of detailed study and the state of this question is fairly fully reflected in a number of works by Borshchevskii published in the period 1936-1939.

The effect of various factors on accident proneness was certainly a subject of study by the Institute, but only two works appeared in print, one by Vishnevskii (1939a), in which he finds that in no case was a connection established between accident and defects in the organ of vision and one by Sobennikov (1939c), in which the author says that "certain flying accidents are connected with the neuropsychic condition of the flier".

Problems of parachuting were the subject of prolonged study by G. R. Graifer, who had started investigating traumatism in parachutists as long ago as 1936 and 1939 produced a detailed work on the medical precautions for parachute jumps, which is to be found in Principles of aviation medicine.

The value of stimulants in flying was first investigated by Subbotnik (1939g). Unfortunately his attention was attracted only to cola preparations and did not extend to looking for and investigating other stimulants. His experimental research on the effect of cola preparations, however, produced much interesting information.

Physical culture was not the subject of systematic work at the Institute and such indications about the necessity of its forming part of a flier's life as are to be found in papers by the Institute's members do not go beyond generally accepted ideas. The forms of physical exercise worked out by Popov and Khilov (1940) and by Kulikovskii (1939a) for training the vestibular apparatus are based not so much on experimental data as on general ideas about the physiology of the vestibular apparatus.

The use of aviation for medical purposes was completely ignored by members of the Institute.

The training of aviation doctors was a constant and central preoccupation of the whole Institute. Its members met a fairly representative cross section of the people in this field at the periodic gatherings and refresher courses. The permanent director of these gatherings, K. K. Platonov, summing up their results, concluded that the aviation doctor, while being primarily a clinician, must have a basic minimum qualification in aviation medicine (Platonov, 1940a). This minimum qualification must include a good knowledge of the description of diseases and methods of aircrew selection and examination, familiarity with the physiology of high-altitude, high-speed and night flying, a good knowledge of oxygen respiratory apparatuses, the techniques of pressure-chamber training, general military health tactics and Air Force tactics.

11

The Institute was undoubtedly the center of Soviet thought on aviation medicine during the first eight years of its existence. It was the scene of strenuous activity on the problems of aircrew physiology, hygiene and examination and everything it did was of great advantage to Soviet aviation. The immense enthusiasm of the whole team, their wide knowledge of aviation medicine, their readiness to tackle the most urgent problems of aviation, all helped the Institute not only to catch up with but to overtake institutes of aviation medicine abroad in regard to a number of practical problems and theoretical conclusions. Soviet medicine therefore has the right to be proud of its daughter, Soviet aviation medicine. There can be no doubt that, if the Institute had been given wider experimental facilities and the opportunity for further development, all the problems marked down for its attention would have been dealt with more thoroughly and extensively. The closure of the Institute in 1943 was quite certainly a mistaken and totally unjustified measure.

THE KIROV MILITARY MEDICAL ACADEMY

The general plan of this book means that I must confine my account of the Kirov Military Medical Academy in this essay to the period from the 1920s to the outbreak of the Second World War in 1941. This has advantages and disadvantages. The story will cover a definite historical period, preceding the war, and this is an advantage; but some of the problems on which members of the Academy worked may seem to be left in the air. This is because much of the work (for example, on the effect of anoxia on the nervous system) was only started in the pre-war years and not completed until after the war. The immense amount of practical experience acquired during the war by our aviation doctors stimulated scientific research at the Academy and was widely used by a number of its departments. I shall therefore describe the work of the departments during and after the war in subsequent essays.

In limiting my account to a particular historical period I shall deliberately exclude reference to the work done by the department of normal physiology on ensuring physiologic conditions for stratosphere balloon crews, as well as the work of the biochemistry department on the physiology of high-mountain ascents and on pressure-chamber tests. These subjects have either been dealt with in previous essays or will be covered later.

The material for this essay consists of theses and individual articles published in the period 1925-1941.

The Academy was very late in starting research on the problems of aviation medicine. Only one if its many departments, Voyachek's ear, nose and throat department, was really interested in the problems of aviation medicine in the problems of aviation medicine in the 1920s and early 1930s. There is every reason to believe that the first work on aviation medicine done at the Academy was Khilov's published in the journal Nasha Iskra in 1925, on the determination of labyrinthine norms for fliers. The great majority of the other departments were drawn into aviation medicine projects only in the second half of the 1930s.

It must be admitted that by no means all the Academy's work on matters which would appear to concern aviation medicine during this period had any immediate relationship to that subject. Professor I. R. Petrov's department of pathophysiology, for example, did a great deal of research on the effect of anoxia on the central nervous system but this, although related to aviation medicine, had no direct bearing on it. The reason was that the department was working mainly on the problem of so-called anemic hypoxia, whereas only hypoxic anoxia could be of interest to aviation medicine. The information obtained by the department of pathophysiology in regard to the difference in the sensitivity of various parts of the central nervous system to anoxia was undoubtedly of interest to aviation doctors, but it must be remembered that the reactions of the central nervous system in hypoxic anoxia are of a quite different kind from those which accompany anemic or ischemic anoxia.

Similarly, the research done by the department of propedeutics of internal diseases (Professor N. N. Savitskii) on oxygen therapy in various pathological conditions was somewhat remote from the problems of aviation medicine; yet despite the strictly therapeutical direction of this work aviation doctors did extract a good deal of useful information from it.

In the same category we must place the extensive morphological research on the central nervous system which Kurkovskii (1941, 1946) performed on animals which had died of asphyxia or anemia, as well as the work done by V. F. Vail' of Professor Maslov's clinic of children's diseases on determining the sensitivity of various animals to anoxia of toxic origin at various stages of ontogenesis (poisoning by sodium cyanide, by prussic acid, by sodium nitrite, by carbon monoxide etc.) (1940, 1943).

We can take it, then, that the Kirov Academy became deeply interested in aviation medicine only in the second half of the 1930s, when the Soviet School of Aviation Medicine was already firmly established in a place of honor in Soviet medicine.

There were reasons for this late involvement of the Academy in aviation medicine. The most important was its lack of facilities for appropriate experiment. The second reason, in my opinion, was the complete or almost complete unfamiliarity of those in charge of the departments and clinics with the conditions of a flier's work and with the problems involved. Lastly, another factor may have had some importance: the department of normal physiology (Academician L. A. Orbeli) was not particularly interested in the problems of aviation medicine. After its interesting work on ensuring physiologic conditions for the Osoviakhim crew in 1933 the department moved rather away from aviation medicine projects. Even after it had acquired an excellent pressure laboratory in 1936 and offered all other departments extensive facilities for working in this laboratory, the department itself paid comparatively little attention to this subject and did not produce any independent research on it until the end of the 1930s; even then, output did not correspond to the strength of the department.

An interesting point here is that in 1935 Brestkin, Egorov and Lemeshkova started interesting work on the effect of anoxia on the activity of the gastric glands. This could have stimulated extensive research on the digestive processes under anoxic conditions; yet the authors dropped it, despite the interest of their initial findings and despite the fact that they were working in the very department formerly directed by Pavlov, where these questions could have been fully solved.

Another typical instance of a missed opportunity was the department's failure to follow up Orbeli's extremely interesting article, The nervous system under reduced pressure (1940). Orbeli offered a brilliant, coherent and profoundly original picture of the peculiar reactions of the C. N. S. accompanying hypoxia based entirely on the principles of evolutionary physiology. The department seemed to stand at the threshold of sweeping research on the subject, based on the Pavlovian method; but it held back and did not start investigating the higher nervous activity until the end of the 1940s.

So, for various reasons, the Academy dragged its feet in regard to aviation medicine until the mid-30s. It took a whole series of internal and external incentives to change the Academy's attitude.

These were indeed forthcoming. The Main Administration of Military Medicine, reviewing the Academy's research projects, kept trying to channel this work in the direction of urgent problems in military medicine, including aviation medicine; but the Academy reacted sluggishly. The Administration administered an important stimulus when it gave the Academy direct orders to set up a research team on the effects of parachuting. The team consisted of A. F. Aleksandrov, Ivanov, Kabanov, A. V. Lebedenskii, Lifshits, Makarov and Skoblo. A series of interesting papers appeared, but that was all.

The Academy received another stimulus in 1933 from Osoviakhim. Admittedly, only the department of physiology was forced to turn its attention to the problems of physiologic conditions for the stratosphere balloon crew. This impetus too would have had no important consequences but for the fact that by this time a group of enthusiastic doctors inside the Academy had started a day-by-day campaign of persuading the various department heads and the Academic Council of the Academy as a whole of the necessity for undertaking the solution of aviation medicine problems. This group included Khilov, Vladimirov, Brestkin, Egorov, Aleksandrov, Zimkin and a number of others.

By the mid-30s several heads of department (Voyachek, Arinkin, Anichkov, Petrov, Vladimirov, Osipov, Astvatsaturov, Savitskii and others) were including aviation medicine topics in their research plans. For some departments, for example the departments of pathophysiology and biochemistry, the work on anoxia, started in the second half of the 1930s, became their main concern in the post war years.

The most important stimulus impelling a number of departments to work on aviation medicine came from the 1939 All-Union Conference on Aviation Medicine. Of the 60 papers read, 25 were by members of the Academy. The Conference vividly showed that a new field of specialization, aviation medicine, had come into existence in the USSR and that it called for very great attention from the departments of the Academy.

Another stimulus came from the progress of Soviet aviation, which by the mid-30s had impressive achievements to its credit. The turning point was 1936, when Orbeli and Brestkin succeeded in installing a special pressure laboratory in the department of physiology, enabling many other departments to carry out experimental work. This was the moment when a series of departments (teaching therapy, pathophysiology, biochemistry, physiology, clinical aspects of nervous diseases and some others) began to engage on the new, intricate and extremely topical problem of anoxia.

Broadly-conceived experimental work in the pressure chambers and tests on the inspiration of oxygen-impoverished gas mixtures, together with the wealth

of factual material collected by Vladimirov during a series of high-mountain expeditions, provided an opportunity for radical revision of all the basic propositions of altitude physiology. All this greatly strengthened the position of Soviet aviation medicine and enabled it to repudiate foreign influences entirely and follow its own independent path. It became an independent scientific discipline, with its own aims, its own methods of investigation and its own corps of aviation doctors, to whom it was a specialization like any other medical specialization.

The main problems on which the Academy worked here were anoxia, the physiology of the vestibular apparatus and, for the E.N.T. departments, determining norms for length of flying service. Apart from these basic problems, members of the Academy worked on problems of parachuting, aviation sanitation and certain hygienic problems affecting the flier.

The problem of anoxia

As this was the main problem for several departments, it accounted for most of the work. The staff now tackled in earnest the urgent problems of hypoxic effects both on the individual physiological systems and on the organism as a whole. Work on most of these questions started in the Academy only two or three years after the war began and were not finally solved, for the work continued after the war; nevertheless, several matters were the subject of detailed investigation. The main work was done in Vladimirov's department of biochemistry and Petrov's department of pathophysiology, but other departments were involved as well.

Effect of anoxia on the organism as a whole. Egorov and Aleksandrov, of Professor Arinkin's department of teaching therapy, were the people mainly concerned with these problems.

One of the first papers on this subject was Egorov's The special characteristics of a flier's work .... (1933), which was not an account of research but a paper read by the author at some special conference held at the Academy. Some of the propositions contained in it deserve attention because they show the author's mental picture of a flier's work. His most typical assertion is that in high-altitude flight the flier must breathe not pure oxygen but a mixture of oxygen and CO_2. Egorov's cautious suggestion that it might be worth adding CO_2 to the oxygen inspired at altitude (The aviator's altitude ceiling, 1931) had thus become an article of faith by 1933.

Again, he categorically asserted that it was essential to establish each individual flier's limit of altitude tolerance (his "ceiling") and enter this in his personal health record.

Lastly, he maintained that hypoxia training by means of his "AE-1" instrument was imperative for all air crew personnel.

These three conclusions were typical of Egorov's thought for a certain period. As his views broadened he again took up a more cautious position in regard to the role of CO_2 and the necessity of adding it to inspired oxygen at altitude. Although references to hypocapnia constantly recur in his works and we sometimes find him insisting that the addition of CO_2 "is a valuable prophylactic, improving tolerance to reduced partial pressure of oxygen" (Egorov, 1937), he no longer confidently maintains that this measure is essential.

Similarly, Egorov does not insist so much on the necessity of establishing individual altitude ceilings for each pilot, confining himself to the demand that "fliers must be graded in terms of altitude tolerance" (Egorov and Ivanov, 1938).

His third conclusion, however, remained a fundamental belief throughout the pre-war period, sometimes even despite the obvious impossibility of improving altitude tolerance by training with the AE-1 instrument. Jointly with Aleksandrov he was to put a great deal of effort into improving this instrument and obtaining its recognition by aviation doctors.

In another work, Contribution to the pathogenesis of altitude sickness, Egorov and Aleksandrov (1934) first reviewed the state of the problem of acidosis and alkalosis under hypoxic conditions and then gave the results of their own investigations, using the Henderson-Pierce rebreather, on 41 patients. These tests are interesting mainly because this was the first time that instead of healthy subjects, persons suffering from some other disease, sometimes a very serious one, were subjected to hypoxia.

Tests on a group of diabetics, for example, showed that although they suffered from chronic acidosis, their general objective and subjective condition was not aggravated, but distinctly improved, when their oxygen supply was reduced. Evidence of the improvement included reduced ammonia content and higher pH of the urine and a lowering of the sugar level both in the blood and in the urine.

Hypoxia tolerance was highest in patients suffering from deep organic variations in the hematopoietic organs and severe, pathological, quantitative and qualitative tendencies in the red blood composition. Erythemics, contrary to expectation, showed no appreciable improvement in altitude tolerance.

Persons suffering from organic heart diseases tolerated oxygen deficiency no worse than completely healthy subjects, but those suffering from various functional disorders of the cardiovascular system showed drastic fluctuations in their tolerance of hypoxia.

It is hard to say whether these tests helped the authors to determine the pathogenesis of altitude sickness. In their conclusions they do not touch on this question at all, but assume that alkalosis, rather than acidosis, occurs at altitude.

Egorov's next work, Study data on the effect of long flights on the flier's organism (1935a) is very interesting too. The work described here was a repetition of his earlier joint research with Dobrotvorskii. On this occasion the pilot and passenger (Egorov) in a two-seater aeroplane flying from Moscow to Leningrad via Orenburg, Borisoglebsk and Odessa, determined their pulmonary ventilation during the flight and took air samples for subsequent analysis. In addition, observations on the condition of the cardiovascular system, weight, body temperature, blood and urine were performed. The figures adduced by the author reveal exceptionally sharp fluctuations; but, if the mean values alone are taken, we find that during the first days of the flight the energy losses were high but that they subsequently reverted almost to normal. The figures for the pilot were more constant, those for the passenger more variable. On the average, the pilot's expenditure of energy under the difficult flight conditions amounted to 125.1 cal, against 97.47 cal under normal flight conditions. It was not possible to establish any direct correlation between the pulmonary ventilation, oxygen demand and energy expenditure.

On the basis of these data Egorov placed the flier's work in a middle category and concluded that the "neuropsychic stress, not allowed for by the gas exchange" was more important than the energy losses. To investigate the latter alone, therefore, was a quite inadequate way of studying the flier's work.

Egorov consolidated all the work mentioned above, together with some of his earlier work, in his doctorate thesis entitled The effect of reduced partial pressure of oxygen on the human organism, which he defended at the Academy in 1936 and issued as a separate monograph under the title The effect of high-altitude flights on the flier's organism in 1937. This was an event of some importance in Soviet aviation, for it was one of the first doctorate theses to be written on the problems of aviation medicine. It was the result of twelve years' work, summarizing, on the one hand, all the experimental material of one of the most eminent specialists in the field and, on the other hand, drawing widely on the physiological literature for its general inferences and conclusions.

The thesis consists of seven chapters and a concluding section. Chapter 1 contains general information on the structure of the atmosphere. Chapter 2, entitled "The effect of the high-altitude climate on the organism", is an extensive review article in which the author draws heavily on Loewy's Physiology of the high-mountain climate (1932) and gave comparatively few conclusions of his own. Some of the material contained in this chapter, however, was completely original. This related to research by the author, jointly with Brestkin and Lemeshkova, on the secretory function of the gastric glands under hypoxic conditions and had formed the subject of a paper read at the 15th International Congress of Physiologists (1935). This material was twice published in the form of separate articles (1936 and 1941). It had been established, from experiments on dogs with Pavlov and Heidenhain stomachs, that the gastric secretion was sharply reduced, both in the reflex and in the humoral phase, under conditions of slight (5000 m) or severe (11 000 m) hypoxia.

The third chapter of Egorov's thesis was concerned with the etiology, pathogenesis and prophylaxis of mountain (altitude) sickness. Here he was not independent. His discussion of the etiopathogenesis of altitude sickness was dominated by the recent works of the American physiologist Henderson and by the prevailing enthusiasm for shifts in the acid-alkali balance, which he regarded as the key factor in the pathogenesis of altitude sickness. He even constructed a separate pathogenesis for the disease, in which, strictly following Henderson, he divided the effect of hypoxia into two stages, a stage of physiologic regulation (from 3000 to 8000 m) and a stage of pathological regulation or asphyxia. In the belief that the basic etiological factor in altitude sickness was oxygen deficiency, he suggested replacing the terms mountain and altitude sickness by a single term "anoxemic disease".

For prophylaxis against altitude sickness the author recommends careful air crew selection and hypoxia training with the AE-4 instrument. After two to three months training every other day, with the oxygen level of the inspired air reduced to 10-8%, the reticulocyte level could be raised from 0.4 to 1.4-2.0%.

In chapter 4, on determining the aptitude and adaptability of the organism to high altitude, the author reproduces old data based on the investigation of 69 fliers using the Henderson-Pierce rebreather (Egorov, 1931) and supplements these results with resports on 36 fliers suffering from various diseases discussed above.

The next chapter gives the results of investigating energy loss by the flier during flight. These two have been mentioned above.

The last chapter, entitled "Medical precautions in stratosphere ascents", contains brief data on method on ensuring physiologic conditions for the crew of a stratospheric balloon, together with the results of the author's own investigations on air renewal in the Chertovskii suit.

Egorov's thesis was thus a sober work, summing up, as it were, a particular stage in the history of Soviet aviation medicine and at the same time a definite stage in the Academy's research record, for this was the moment when the research attack on the problem of anoxia developed on a much wider front. The emphasis was switched to separate, detailed problems of the effect of hypoxia on the individual physiological systems.

Effect of hypoxia on the C. N. S. This was mainly the concern of two departments, the department of nervous diseases under B. V. Doinikov, in which D. I. Panchenko was the person responsible, and the department of pathophysiology under I. R. Petrov. The work started only in 1939 and the bulk of it was done in 1940 and 1941. The two departments worked along completely different methodological lines. Panchenko's investigations were exclusively on clinical patients subjected to the effects of reduced atmospheric pressure, whereas Petrov carried out extensive experimental work on animals in which the anoxia was induced by a wide range of techniques - stopping the respiration and blood circulation, tying the blood vessels, blood letting and so forth.

Orbeli's paper on The nervous system under reduced pressure (1940) stood by itself. The author's basic idea was that under everyday conditions the activity of phylogenetically old parts of the central nervous system were regulated by the cerebral cortex but that when the cortical activity was depressed the subcortical parts were released from the regulating influence of the cortex and so to speak, let loose. Our normal behavior was inhibited, but under the influence of reduced partial pressure of oxygen, with the consequent depression of the cortex, a man was reduced "to the position of a slave to his own organism and to the inherited forms of behavior retained by his nervous system". Hence the peculiar behavior of people under conditions of hypoxia.

Further, Orbeli stressed that oxygen deficiency acted as a "direct or almost direct" stimulant on the higher vegetative centers and, in particular, the centers of the sympathetic system situated in the hypothalamic region. This explained all the vegetative reactions occurring at altitude. The interest of this paper lies mainly in the fact that it gave the first complete picture of the human organism's reactions at altitude. Reinforcing Strel'tsov's views, explained earlier in this chapter, concerning the paramount influence of hypoxia on the cerebral cortex, it set a trend characteristic of Soviet physiological science. Foreign investigators studying the effect of hypoxia on the C. N. S. had not been able to get further than a rag-bag collection of contradictory facts; the Soviet school relying on Orbeli's conception, now began to follow a clear-cut and consistent line of thought.

Panchenko was one of the first to adopt Orbeli's conception of the prime vulnerability of the phylogenetically young formations of the C. N. S. and in his thesis, The effect of hypoxemia on certain functions of the human nervous system (1941a), he energetically upheld this principle, although his facts did not always fit the theory.

Panchenko studied the variations in the reflex and sensory spheres at various altitudes in "many thousands" of healthy individuals and in a group of patients suffering from various organic diseases of the C. N. S. These included disseminated sclerosis, Parkinson's disease, syringomyelitis and other diseases. Both the "many thousands" of healthy subjects and the patients were "raised" to 6000 m, sometimes 7000, in the pressure chamber and the variations in their reflexes and sensibility were traced. Despite the undoubted interest of the task Panchenko had set himself, his neglect of the basic moral principles of society in performing extremely dangerous experiments on gravely-ill people is surprising. Reading the records of these experiments, in which people suffering from Parkinson's disease were raised to 6000-6500 m, it is difficult to accept his contention that they had no harmful effect on the state of health. Even more difficult to understand is the fact that not a single voice was raised in the Academy to protect these people, who had gone trustingly to their doctor, in the belief that the pressure-chamber ascents were a new method of therapy.

The results of Panchenko's tests and observations inspire only one feeling, disbelief. It is enough to say that in his "many thousands" of healthy subjects he

detected no changes whatsoever in the reflex and sensory spheres even at 6000-6500 m. These changes were observed by him only at 7000 m. Yet he detected changes in the clinically ill subjects at lower altitudes. The tendon reflex, for example, as a rule diminished at 2000 m and rose at 5000-6000 m among the clinically ill; in the healthy, however, the author detected no changes at all in this reflex. The pathological reflexes of the clinically ill were observed to intensify with altitude, while the abdominal reflexes were reduced or disappeared; in the healthy, the author observed no variations whatsoever in the abdominal reflexes at altitude. Even at 4000 m there was a rise in the subcortical reflexes among the clinically ill group but again the author observed no change in the healthy. At 4000 m Babinskii's (Babinski's) sign, Doinikov's symptom, the Barré syndrome and the Buddha phenomenon appeared in the ill subjects but not in the healthy. At the same altitude the former group started to suffer disturbance of the tactile sensations and above 5000 m disturbances of all the other types of sensation as well; in the healthy group, the tactile sense did not start to suffer below 6000 m, the sense of pain became disordered only at 6500 m, the temperature sense at 7000 m and the muscle-and-joint sense at 7500 m.

If we are to believe Panchenko, he seems to have interpreted all these data as indicating that hypoxia had no effect whatsoever on the C.N.S. of a healthy individual, or at least only at altitudes above 6000 m. Alternatively, he would have had to draw another inference: namely, that the techniques currently accepted in neuropathology for investigating the nervous system were not able to reveal any such effect. This was the only correct conclusion directly following from all his investigations. But he did not draw it. Instead, relying exclusively on data obtained from a group of sick people and totally ignoring the results of his own investigations on "many thousands" of healthy people, he developed the notion that under hypoxemic conditions the first part of the central nervous system to suffer consisted of the phylogenetically new elements of the brain, that the root cause of the reflex, sensory and motor disorders occurring at altitude in the selective action of hypoxemia on the cortical elements of the brain, that the whole concatenation of changes in the central nervous system observable at altitude must be regarded as a disorder of the normal processes of excitation and inhibition in the cerebral cortex and so forth.

The gap between the results of his investigations on the healthy subjects and the theoretical discussions is so wide that he is unable to fill it with any data relating to the clinically-ill subjects. Yet he sometimes lets slip isolated statements that ill accord with his own basic conception. He suddenly says, for example, that the "general deafening and lowering of efficiency" observed at altitudes above 4500-5000 m, depends on the "effect of hypoxemia on the non-encephalic part of the brain" (page 53).

The department of pathophysiology approached the study of the C.N.S. reactions quite differently. Petrov, making extensive use of various methods of experimentally-induced hypoxia (the anemia method, the asphyxia method, the oxygen-impoverished gas mixture inspiration method) obtained a number of interesting data, which he published in four papers issued between 1939 and 1941.

His main work during this period was a long article in Klinicheskaya meditsina in 1939, entitled Functional change in the central nervous system accompanying various forms of hypoxemia. The other articles, in the symposia Hypoxia and its control (1939-1941), were only supplementary to this main work, adding certain details.

As a result of a series of experiments in inducing anemia of the brain Petrov reached the conclusion that of all the bulbar centers the most sensitive to hypoxia was the respiratory center. This, he believed, not only regulated the breathing but also played a definite role in regulating the blood circulation. He did not formulate the idea of irradiation of excitations from the respiratory to the vasomotor center until much later. For the moment, he merely stated that excitation of the appropriate receptors (the receptor zones of the vascular system) were transferred to the vasomotor center through the respiratory center. Yet he regarded the latter as a peculiar form of receptor of the vasomotor center.

Another important conclusion was Petrov's recognition of the central regulation of the blood circulation. At a time when the Heymans and Herring schools were categorically denying independent central regulation of the blood circulation, Petrov, believing that this regulation was effected only by a reflex path as a result of stimulations to the aortic and sinocarotid bodies, not only recognized the independence of the central regulation of the blood circulation but believed that the central pressor regulation was more powerful than the reflex regulation. Experiment convinced him of this: after extirpation of the pressoreceptive nerves (by denervation of the carotid sinuses and section of the depressors) the organism still reacted to hypoxia by raising the arterial pressure. Petrov says boldly; "At present there are no sufficient grounds for reducing the regulation of the blood circulation, even under physiologic conditions, merely to the reflex regulation".

This conclusion was very important for the understanding of all blood-circulation reactions accompanying oxygen deficiency, for it was based on recognition of the possibility that hypoxia directly affected the bulbar centers.

Lastly, experiments in which test animals were asphyxiated, then revived, enabled Petrov to establish which parts of the C. N. S. were most sensitive to hypoxia. His investigations showed that the first function of the C. N. S. to be restored after fatal asphyxia was the excitability of the bulbar centers (respiratory, vasomotor and vagus nerve centers). Some time after this, signs of functional restoration of the mesencephalon, then of the spinal cord appeared; the functions of the diencephalon and cerebellum were estored still later and last of all the functions of the cerebral cortex.

Thexe experiments once again gave support to the contention that the phylogenetically oldest formations of the central nervous system were the most resistant to hypoxia (the medulla oblongata, the spinal cord and the mesencephalon) and that the most sensitive were the phylogenetically younger formations (the cortex and cerebellum).

Such are the principal conclusions to be drawn from Petrov's four 1939-1941 works. I have not described his experiments in detail, as their relationship to aviation medicine is remote, but the above-mentioned conclusions are the key propositions on which all aviation physiology rests.

There is one more point, however, in Petrov's experiments, which aviation doctors cannot ignore. This is his advocacy of breathing a mixture of oxygen and CO_2 at high altitudes, instead of pure oxygen. He does not say this in so many words but he does constantly emphasize that some accumulation of CO_2 in the organism is beneficial in hypoxia. Not solely because of increased oxyhemoglobin dissociation but rather because "we have here an example of the little-studied direct biological effect of CO_2 on the tissues".

This makes an odd impression. After the practical experience of aviation in all countries had shown that only pure oxygen must be breathed at high altitude, after Kokkinaki, breathing pure oxygen, had established a world altitude record of 14,575 m, after special research had shown that the addition of CO_2 to the oxygen inspired at altitude had no useful effect whatsoever - after all this, it is curious to find Petrov re-opening the CO_2 question and talking about its playing some special role in hypoxia.

It would have been extremely important if Petrov's conclusions about the non-uniform sensitivity of the various parts of the C.N.S. to oxygen deficiency could have been supported by morphological data; but this did not immediately happen.

What did happen was that Goldshtein, working in the department of pathological anatomy, performed experiments on rabbits kept at pressure-chamber equivalents of 6000 and 8000 m for periods varying from 2 to 72 hours and found that in every case irreversible structural disturbances could be detected in the heart, liver, kidneys, lungs, spleen, bone marrow and certain other organs. As regards the brain, Goldshtein (1939) wrote that "the brain shows no morphological changes for a comparatively long time, despite a whole series of functional disturbances of the central nervous system" in the experimental animals. According to Goldshtein, severe lesions of the nerve cells of the brain were observed only after the animal had remained for three days at an altitude equivalent of 8000 m.

The explanation seems to lie in some "technical imperfection in the microscopic investigation", for in 1940 Kurkovskii, who was engaged in a special study of alterations in the central nervous system accompanying hypoxia, had succeeded in showing the presence of a wide variety of morphological changes, often very severe, in the nerve cells of the brain. Admittedly, hypoxia had been caused not by remaining at altitude in a pressure chamber or by breathing oxygen-deficient gas mixtures, but by asphyxia, causing a suspension of the respiration and heart beat in the animal for some time.

It turned out that after asphyxia lasting for 4.5 to 6.5 minutes (cessation of breathing for 7.5 to 12 minutes, cessation of cardiac activity from 2.0 to

2.5 minutes), isolated degenerative changes could be detected in the nerve cells situated in various layers of the cortex. Much more severe changes were detected in the horn of Ammon and the cerebellum.

If asphyxia lasted 7-12 minutes, with cessation of breathing for 8-16 minutes and of cardiac activity for 3 minutes, the changes in the horn of Ammon and the cerebellum were of roughly the same order but those in the cortex were more severe. In a number of cases the changes in the cortex were of the nature of ill-defined focal collapses containing hardly any nerve cells. All the nerve cells of the first three cortical layers perished in the cortical convolutions and completely disappeared. In these parts of the cortex an extreme proliferation of all types of gliae was observed and it was primarily the proliferating astrocytes that decayed; but the brain stem and spinal cord showed little change.

If asphyxia lasted from 13 to 24.5 minutes, with cessation of breathing for 16 to 23 minutes and of cardiac activity for 4 minutes, the morphological changes in the brain were even more pronounced. Extensive focal malacia or destruction of the nerve cells was detected in nearly all layers of the cortex. In some cases the corpus striatum underwent severe modification. Severe changes were detected also in the horn of Ammon and the cerebellum. The majority of the cells of Purkinje in the cerebellar hemispheres were found to be seriously diseased. The stem part of the brain was again hardly affected.

These data indicated that even a two-minute cessation of the cardiac activity caused irreversible degenerative changes in the horn of Ammon, usually localized in the pyramidoid area. Longer cessation of the cardiac activity caused irreversible and severe morphological changes both in the cortical and in the cerebellar cells.

Morphological investigations had thus corroborated the hypothesis: namely, that the phylogenetically younger parts of the C.N.S. were the most vulnerable and the phylogenetically older parts the most resistant to hypoxia.

After the war the reactions of the C.N.S. to oxygen deficiency described here were thoroughly investigated by pathophysiologists and morphologists.

Effect of hypoxia on the blood circulation. Before the war there was hardly any direct investigation of the circulatory reactions to hypoxic conditions but the Academy did produce several papers directly or indirectly touching on this question.

One of the first was Egorov's Requirements in regard to the condition of the internal organs in entry and routine medical examinations of flying personnel (1935b). From its title, this work seems to have little direct bearing on the question we are discussing here, but in fact three-quarters of it concerns the cardiovascular system. The author regards oxygen deficiency as the greatest hazard in flying and discusses a number of interesting matters closely connected with its effect on the blood circulation.

These turn on two key questions: can cardiac hypertrophy develop in the flier as a result of his work and is there anything in the profession itself which lays the flier open to the risk of early sclerosis and premature deterioration of the cardiovascular system?

In answer to the first question Egorov points out that the theoretical prerequisites for the development of cardiac hypertrophy in a flier do exist and that the "heart can suffer hypertrophy", since the flier's job involves a number of factors adversely affecting the work of the heart. This risk occurs, however, only if the selection rules are not observed and prophylactic measures are not taken; otherwise, "conditions can be created for the flier to function at any altitude without the occurrence of any special cardiovascular aberrations in a hitherto healthy person".

The answer to the second question was roughly the same. "From the etiological point of view there is not the slightest reason for connecting the flying profession with early (occupational) arteriosclerosis". Every diagnosis of arteriosclerosis in a flier must be put down to wrong selection; in other words, the patient already had a predisposition to pathological cardiovascular reactions before he took up flying. Egorov does, however, make the reservation that: "it would be a disservice to try and make out that flying had no effect at all on the cardiovascular system, but its effect amounts only to that of a contributory factor and then only where there is a definite pathological basis to start with".

These are remarkably elastic propositions. On the one hand, there are theoretical grounds for the development of cardiac hypertrophy in a flier; on the other hand, it would be harmful to claim that flying has no effect at all on the flier's cardiovascular system, and yet "there are no grounds for speaking of any kind of pathological effect of the flying profession" on the cardiovascular system. It is deeply to be regretted that this crucial judgment was made without sufficiently thorough study of the question, without any statistical data whatsoever, without studying case histories, without reference to the medical examination records of fliers who had been grounded or to the records of the Medical Disabilities Board; for this conclusion was not Egorov's alone but that of Arinkin's department and, indeed, of the Academy as a whole.

Another paper by Egorov, bearing the committed title *The effect of reduced atmospheric pressure on the blood circulation and morphology* (1939b), which appeared as a separate chapter in the book *Principles of aviation medicine* is extremely thin. All the reader can tell from it is that under hypoxic conditions the pulse quickens, the blood pressure rises and altitude collapse is caused by paralysis of the extracardiac nerve centers. There are no electrocardiographic data at all, no information on the stroke and minute volume of the heart, on the character of the blood circulation in particular regions or on the venous blood circulation.

In September 1940 Egorov gave his views on the effect of oxygen deficiency on the blood circulation in a somewhat expanded form in a paper read to the

Leningrad Therapeutic Society, on The effect of hypoxemia on the blood circulation. In an attempt to explain hypoxemic hypertension as due to inadequate oxygen supply to the vasomotor centers, he does here adduce certain data on the enlargement of the minute volume, the rise in venous pressure accompanying hypoxemia and the electrocardiographic changes with altitude; these data, however, were not his own but those of two clinicians, Arinkin and Savitskii.

The latter's coworkers published three works: Lesnik (1941) wrote on the variations of the mean arterial pressure in anoxia, Molchanov (1941) on the electrocardiography in reduced partial pressure of oxygen and Tsygankov (1940) on the partial electrocardiogram under conditions of physical strain and anoxia.

Lesnik, after investigating 50 healthy and ill subjects, concluded that the mean arterial pressure did not alter under conditions of anoxia, either in healthy subjects or in fully-compensated cardiovascular patients.

Molchanov reached the conclusion that in healthy subjects reduced partial pressure of atmospheric oxygen caused negligible changes in the electrocardiogram but that these changes were sharper in the sick subjects even at low degrees of anoxia.

Both Lesnik's and Molchanov's results were insignificant, largely because their investigations were performed not in the pressure chamber but with an AE instrument.

In contrast to these authors, Tsygankov performed his electrocardiographic investigations in a pressure chamber, in which the subjects were kept at 5500 m for 12 hours. He almost invariably observed a reduction in the voltage of the initial ventricular complex and a thickening of T. The fact that the variations on the electrocardiogram were of a completely reversible character is very important, the best results being obtained from a group of highly-trained athletes.

Among the questions directly bearing on the effect of oxygen insufficiency on the blood circulation, one is of profound interest to all aviation doctors: the mechanism of altitude collapse. It is interesting to see what Egorov's views on this question were, for he frequently had occasion to observe cases of collapse in the course of his practice.

Unfortunately, he does not seem to have reached any definite view on the mechanism of altitude collapse or, as he sometimes called it "hypoxemic collapse".

In his book The flier's threshold (1931) Egorov distinguishes three types of collapse due to lack of oxygen: 1) collapse due to cardiac weakness, 2) collapse due to vascular insufficiency and 3) collapse of combined origin, due to cardiovascular insufficiency.

In another of his books, published in 1937 (The effect of high-altitude flights on the flier's organism) Egorov is more confident that the reason for collapse is inadequate blood supply to the heart, but here again he adduces, as a thoroughly well-grounded view, Henderson's belief in hypocapnia as the reason for altitude collapse.

Many of Egorov's 1939 papers reveal difficulty in making up his mind about the mechanism of altitude collapse. At times he inclines to his earlier view that it is due to a reduction in the amount of circulating blood and to an inadequate supply of blood to the heart; at times he supports the hypocapnia theory; at times he adopts the view of the German investigators Opitz and Tilman, and also Koch, who regard collapse as a manifestation of paralysis of the extracardial nerve centers.

In The effect of reduced atmospheric pressure on the blood circulation and morphology, for example, Egorov develops Koch's view, but in another work, General training for high-altitude flight, he reverts to his own opinion that altitude collapse is the result of cardiovascular insufficiency combined with an inadequate supply of blood to the heart; yet he expounds this view without any critique of the Koch paralysis theory. In his third work in the same year, An experiment in studying the adaptability of the organism to reduced partial pressure of oxygen, he repeats more or less word for word what he said in his previous work. Lastly, in his paper addressed to the Leningrad Therapeutic Society on 27 September 1940, he does not say a word about the therapy of paralysis of the extracardial nerve centers but continues to uphold his own former view about vascular insufficiency accompanied "apparently by an inadequate supply of blood to the heart". He was particularly insistent on this, for Petrov had demonstrated the failure to establish experimentally the existence of hypoxemic collapse due to primary acute insufficiency of the peripheral blood circulation. "It is perhaps not always given to the pathophysiologist to be in advance of the clinician", he says. It might seem as though by 1940 he had finally made up his mind, but he had not, for the same paper contains the assertion that hypocapnia can contribute to hypoxemic collapse.

I do not imply that Egorov's vacillations were in any sense unnatural or his experience in this respect was very different from that of every investigator engaged on a particular problem for a long time. He was prevented from reaching a definite opinion on the mechanism of altitude collapse because of the total lack of experimental work at the Academy in regard to the effect of hypoxemia on the blood circulation and also because the problem was completely pushed aside, not only by his own department, but also by a number of other departments in the Academy. The result was that the Academy failed to work out a unified view on the matter, despite its immense importance for aviation medicine.

As we see, the works on the influence of anoxia on the blood circulation show that in this field the Academy performed no thorough experimental work and its net contribution to the subject added very little to the ideas aviation doctors already held.

All these data on the effect of oxygen deficiency on the blood circulation had to be supplemented by Goldshtein's morphological investigations (1939, 1941). Goldshtein found that after a few hours at 6000 m an animal developed adipositus cordis and that after three days necrotic changes supervened as well. At 8000 m such changes occurred after only 36-48 hours.

Effect of anoxia on the blood. The main line of work in Arinkin's department was hematology and it was hardly to be expected that the department would be uninterested in morphological changes in the blood due to anoxia.

The first work on this subject to emerge from the department was a paper by Kozlovskaya and Kryukova, published in 1934, on the morphological changes in the blood during high-altitude flights. These investigators were satisfied that a single flight at 4500-6000 m without inspiring oxygen after remaining at that altitude for more than one hour produced no important changes in the red-blood picture, but that more than one ascent to the same altitude, even for shorter periods, resulted in a clear picture of blood regeneration, expressed as an increase in the erythrocyte and reticulocyte count. In regard to the leucocyte count it was established that a single altitude flight elicited relatively sharp neutrophilia but that multiple flights elicited no important changes in the white blood except for some increase in the monocyte count.

The department did not return to this question for four years and extensive research on it did not develop until V. B. Farber's arrival. His thesis, entitled The influence of hypoxemia on the morphological composition of the peripheral blood and sternal punctate (1939a), and a number of subsequent papers on the same subject shed light on the manifold and intricate changes in the blood morphology developing under conditions of hypoxia, as well as on the complicated problem of the polyglobulin mechanism at altitude.

Farber performed parallel investigations on peripheral blood and on the sternal punctate, which enabled him to compare the alteration in the peripheral blood with the condition of the erythroblastic process of the bone marrow. His test subjects were healthy persons who stayed in the pressure chamber at 5500 m for 24-hour stretches. One of them spent 9 periods of 24 hours in the pressure chamber every 5 days.

After one day under these conditions the hemoglobin level rose by 8-12%, the erythrocyte count increased by 520,000 (minimum) and 2,320,000 (maximum), the color index fell by 0.1-0.2, the thrombocyte count rose by 50,000-190,000, the reticulocyte count quadrupled (from 0.1 to 0.4%), the leucocyte count fell by 450-1200 and a slight leftward shift due to neutrophil and a tendency to monocytosis were observed. Such were the changes in the peripheral blood.

The variations in the bone marrow amounted to a three- or fourfold increase in the proerythroblast count, accompanied by some rise in the erythroblast count and a marked increase in the megakaryocyte count; the leucoblastic process was found to be in a state of depression.

After nine days in the pressure chamber the peripheral blood had undergone the following changes. Hemoglobin, erythrocytes and reticulocytes increased after each stay in the pressure chamber, the maximum increase setting in after the sixth day spent in the chamber and subsequently slowing down. In the intervals between ascents the hemoglobin, erythrocyte and reticulocyte count fell, but did not reach the initial levels.

The variations in the bone marrow fully corresponded to those in the peripheral blood. This justified the author in concluding that the erythrocytosis observable after the pressure chamber ascents should be regarded as a manifestation of physiologic (compensatory and regulatory) mechanisms. The onset of erythrocytosis, in his opinion, must certainly be connected with erythropoiesis; there was evidence for this in the alteration of the erythroblastic process in the sternal punctate.

Such were Farber's principal contentions. He greatly developed and supplemented some of these after the war.

In his 1939 and 1941 papers Egorov added hardly anything to the data I have already mentioned regarding the effect of hypoxemia on hematopoiesis.

It should be added that, according to Goldshtein's morphological investigations (1939, 1941) manifestations of moderate hyperplasia of the hematopoietic tissue could be detected in the bone marrow of animals kept at 6000 m for some tens of hours.

Effect of anoxia on the digestion and metabolism. As I said in the introduction to this chapter, the Academy carried out no thorough experimental work on the behavior of the digestive processes under conditions of anoxia. Brestkin, Egorov and Lemeshkova had started work in this direction in 1934 and obtained interesting data, discussed above, but the subject was then dropped.

Most of the work on metabolism was done in Vladimirov's department of biochemistry. To settle a number of immediate questions Vladimirov and some of his coworkers made a series of high-mountain ascents, performed many interesting pressure-chamber experiments and finally produced a coherent picture of the metabolic effects of anoxia. I shall describe all this in another section.

Vladimirov's data were supplemented by results obtained by members of other departments working on metabolism and tissue respiration. A. F. Panin, for example, of the department of physiology, produced interesting new data on the gas and nitrogen metabolsim under conditions of oxygen deficiency. His thesis, entitled The influence of the protein load on certain gas and nitrogen metabolsim indices in dogs under conditions of acute hypoxemia, defended in 1941, provides the investigator with a series of new, valuable and carefully verified facts supplementing Vladimirov's works on protein metabolism.

Under this heading we must include Danilov's works on the effects of reduced atmospheric pressure on gas exchange and tissue respiration in animals

(Danilov, 1941, 1943 etc.). Here he was concerned not so much with the effect of reduced pressure in itself as with its after-effects. He was satisfied that the pulmonary ventilation in dogs decreased a few minutes after they had been kept at altitudes of 6000-8000 m for 2-6 hours, that the CO_2 evolution fell sharply and that the oxygen demand either increased or remained unchanged. The tissue respiration of the liver increased but there was very little change in the tissue respiration of other organs.

Effect of anoxia on the kidneys. In marked contrast to the general apathy of the physiology department in regard to anoxemia, Kuznetsov produced a thesis on its effects on the renal function (1940). This was a solid piece of experimental research, which still commands attention, for the results obtained provided the first clear picture of the renal function under hypoxic conditions. Kuznetsov used six dogs with separately dissected ureters. The dogs were raised to 8000 m in the pressure chamber; urine samples were taken from each kidney at fixed intervals before, during and after the ascent. Blood samples were taken at the same time. Creatinine analysis of blood and urine samples taken simultaneously enabled Kuznetsov to calculate the filtration and reabsorption by using Rehberg's formulas.

He established that diuresis was sharply reduced at altitude, mainly because the rise in the resorption rate did not keep pace with the fall in glomerular filtration. The reason for oliguria at altitude, in his opinion, was that the glomerular vessels were constricted as a result of lack of oxygen, so that filtration and diuresis were correspondingly reduced. Experiments involving section of the splanchnic nerve showed that this operation had no substantial effect on the diuresis picture. Kuznetsov therefore concluded that the effect in question was only of a humoral nature.

Although he regarded the construction of the glomerular vessels as the reason for altitude oliguria, Kuznetsov nevertheless believed that certain other humoral factors contributing to the functional regulation of the kidneys played a part in this. He attributed the main role to the hormones of the posterior pituitary and to adrenalin. Both these hormones, vasopressin and adrenalin, cause construction of the glomerular capillaries if oxygen is deficient, so causing severe oliguria.

But the reduction of glomerular filtration in response to anoxia is only one aspect of the renal function at altitude. The other aspect, as Kuznetsov showed, is the simultaneous increase in the rate of reabsorption as compared with filtration. This rise in the reabsorption rate was directly proportional to the degree of anoxia. It was nevertheless established that under conditions of hypoxemia only the cloacal reabsorption of water increased; chloride reabsorption fell.

These physiological data were supplemented by morphological research by Goldshtein (1939, 1941), who found that renal polyemia and accumulation of fat globules in the thick sections of Henlé's loops inevitably occurred in rabbits

kept at 6000 m for 2-48 hours. Similar changes occurred if the animals were kept at 8000 m for only a few hours.

Effect of anoxia on the function of the visual analysor. The only pre-war work on this subject was done by A. M. Davydov of Professor Savitskii's clinic (1941). Using the AE-4 instrument, he investigated changes in the ocular photosensitivity of nine healthy subjects and eighteen patients suffering from various cardiac diseases under conditions of anoxia. He found that it was much lower in cardiovascular patients with compensation disorders than in healthy subjects, although it was reduced in both. In the cardiovascular patients some loss of photosensitivity occurred with even a very slight reduction of the atmospheric oxygen concentration; an ascent to 1000-1500 m was enough to impair ocular photosensitivity in the subjects suffering from decompensation; no such effect was observed in the healthy subjects below 3500-4200 m.

This difference suggested that ocular photosensitivity under conditions of anoxia could be used as a test for latent cardiovascular insufficiency, since "the altitude ceiling at which the eyes' sensitivity perceptibly decreases is inversely proportional to the degree of cardiovascular compensation".

The anoxia test as an examination method. Davydov's conclusion was fully in line with inferences already drawn by other members of the Academy. As soon as the Aleksandrov-Egorov instruments AE-1, AE-2, AE-3 and AE-4 had appeared, both the inventors themselves and representatives of other departments had begun saying that these instruments could be used to detect various latent disorders. In other words, it was suggested that anoxia could be used as an aircrew selection and examination test.

Egorov was particularly insistent in defending this view. He even inserted a special chapter in his thesis, entitled "Anoxia as a method of cardiovascular functional diagnostics". One of the conclusions in this chapter is the statement that a test based on rapidly-increasing anoxia revealed the functional adaptability of the cardiovascular system and could therefore be used as a supplementary diagnostic method.

Among the first people to use and at the same time test the efficacy of this technique were N. N. Timofeev, of Professor Osipov's psychiatric clinic, and M. M. Gordon, of Professor Astvatsaturov's nervous disease clinic. They attempted to use the AE-1 to detect C.N.S. insufficiency and for early diagnosis of C.N.S. lesions (Timofeev and Gordon, 1936). They reached the conclusion that the AE instrument was "a valuable yardstick for judging the degree of the nervous system's tolerance of hypoxia" and they believed that it would be worth using the instrument in the diagnosis and objectivization of "obscure and rudimentary forms of organic lesion of the central nervous system, and for discovering the degree of its insufficiency". A little later, Egorov and Ivanovskii (1938) again raised the question of using acute anoxemia as a method of diagnosing functional disorders of the cardiovascular system. Using Bremzer's formula, they investigated variations in the stroke and minute volume of the heart in

cardiovascular patients under conditions of gradually reduced partial pressure of oxygen in the inspired air. The results indicated that the AE apparatus revealed an increase in both volumes accompanied by reduction of the peripheral resistance.

The implication was that reduced partial pressure of oxygen increased the demands on the flier's cardiovascular system and that, consequently, tests with the AE apparatus could reveal various functional disorders of the cardiovascular system.

A number of departments (nervous diseases, psychiatry, general therapy, not to mention the teaching therapy department) thus agreed that it would be worth using the AE apparatus for diagnosing functional diseases of the cardiovascular system as well as for discovering the early forms of organic diseases of the central nervous system. One might think this would have been enough to get the device widely adopted by the Medical Boards; most of them, and particularly the Institute of Aviation Medicine, might have been expected to see the value of this new diagnostic technique. But it was not to be. As the years went by, less and less attention was paid to Egorov and Aleksandrov and after the war no more was heard. The present attitude to the AE instruments consists in writing them off, without any justification, as quaint but useless antiques.

How did it happen? Why should this sensible and interesting suggestion, which could have greatly enriched the techniques of investigating functional disorders and which had received approving comment from several departments, be consigned to oblivion?

There were many reasons. The main reason was that Arinkin, as head of the department, did not support Egorov and Aleksandrov in their proposal, and consequently the Academy as a whole did not support them. This in turn was because the inventors themselves had not completed their work with a sufficient number of exhaustive investigations to test the instrument specifically for examination purposes and thereby clearly demonstrate its utility to aviation doctors. Instead, they kept improving the design, until in the end they themselves had produced no exhaustive list of the specifications of any single modification. It should be remembered, too, that their main concern was to get the apparatus adopted in training schools, for the purpose of accustoming fliers to hypoxia, rather than to improve functional diagnostics. Such proposals looked too simple and elementary to arouse sympathy at a time when a great many units were already equipped with pressure chambers. Many aviation doctors, therefore, looking askance at the AE apparatus as a training device, overlooked the other side of the matter - the possibility of using it for examination purposes. The mistake, excusable in individual doctors, was inexcusable in both the Institute of Aviation Medicine and the Air Force Central Psychophysiological Laboratory where medical-examination questions rated fairly high.

Training and habituation to hypoxia. All that I have said above is confirmed in numerous articles by Egorov and Aleksandrov on the problems of training and accustoming the organism to reduced partial pressure of oxygen.

Even in his first paper on the question (1934) Aleksandrov reached the conclusion that it was essential to classify all aircrew personnel according to the individual's tolerance to oxygen deficiency, on the basis of the AE test. At the same time he and Egorov (1934) compiled very detailed instructions for the use of this instrument.

In his thesis, Egorov (1936) squarely stated that "we have come to the conclusion that, by using devices that bring about even a slight reduction in the partial pressure of oxygen, we can improve the organism's adaptability to high-altitude flights" (page 37). Further, writing of the AE-1, Egorov adds: "by using this very simple technique we can find out whether the organism is well or poorly adaptable to reduced pressure of oxygen" (page 103).

All this shows that Aleksandrov and Egorov regarded their apparatus mainly as a device for training fliers to withstand altitude. It is very difficult to say whether it would have been effective for this purpose, since for a long time there were no comparisons with the altitude tolerance produced on the same subject by pressure-chamber training. Admittedly, the authors relied on data relating to 69 fliers who were supposed to fly at 5000 m without oxygen for one to one and a half hours after undergoing training with the AE apparatus. But their table gives the figures for only 41 subjects, in 12 of whom the results were good, in 13 satisfactory and in 11 poor. If all these fliers had actually flown at 5000 m there would have been some data on which to judge the efficiency of the AE apparatus; but in fact, only 16 of the 41 did so and in 7 the results of AE training were good, in 7 satisfactory and in 2 poor. All withstood high-altitude flight well and obviously no definite conclusions could be drawn from these data.

In short, the question as to whether the AE was an effective instrument for improving altitude tolerance long remained unanswered. Finally, in 1939, a new work by the two authors appeared, entitled General training for high-altitude flights. This described tests on a large group (120), in which the results obtained with the AE apparatus were compared with the results obtained by pressure-chamber ascents to a ceiling altitude; but once again the flight doctor received no clear guidance because the authors for some reason stopped classifying the subjects in terms of good, satisfactory and poor tolerance and instead began to take into account only the length of time during which the subject had used the apparatus. They did not enquire how much atmospheric oxygen remained in the bag nor did they determine the cardiovascular reactions. The authors themselves admit that "it is impossible to reach a definite estimate on the basis of the time factor alone" (page 39), yet they immediately go on to give a definite estimate, saying that although the pressure-chamber tests were not "strictly parallel to the results of the tests producing only reduced partial pressure of oxygen (the AE test) this does not in the slightest reduce the importance of the method we have suggested" (page 39).

The inference, of course, is clear. Egorov and Aleksandrov had used for their comparison the highly uncharacteristic index of time, had even so found no parallelism between the AE and the pressure-chamber tests, yet still

maintained that this made no difference to the value of the technique they proposed. Any aviation doctor would draw a totally different conclusion. All this makes it understandable that the AE apparatus was not recognized as a training instrument by anyone except its inventors. In 1940, however, they themselves, in a paper entitled A facility for training aircrews for high-altitude flights said: "Our first instruments, the AE-1, -2 and -3, did not meet the requirements of training technique" and went on to explain that the AE-4 did not do so either. This induced them to design the AE-5, with which the trainee could stay for almost an hour in an atmosphere with a given desired concentration of oxygen. This device was approved as suitable for training purposes by a special board of the Institute of Aviation Medicine and the authors themselves kept urging aviation doctors to make parallel tests with their instrument and with the pressure chamber; but the war intervened and the AE-5, like its predecessors, did not win recognition.

The AE instruments thus failed as a means of improving anoxia tolerance, but could have been used to diagnose functional diseases of the cardiovascular and nervous systems. But the aviation doctors did not pay due attention to this and so the instrument was forgotten.

Many people had become interested in the training and adaptation of the organism to altitude: Vladimirov, Egorov, Aleksandrov, Petrov, Farber, Kudrin and others. Here the main works were written by Vladimirov, Egorov, Aleksandrov and Kudrin. Vladimirov's views on these processes will be dealt with later. First I shall say a little about those of the three others, all members of Arinkin's department.

Aleksandrov and Egorov (1939) did very interesting work in this field. They took a large group of athletes (63 leading sportsmen) a group of fliers (43) and a group of Red Army men (15) and subjected all three groups to the maximum degree of anoxia each could tolerate in the pressure chamber. The purpose was to find out what form of sport best promoted altitude tolerance. The athletes included 7 weight lifters, 9 players of various games, 9 swimmers, 13 gymnasts and fencers, 15 rowers and 10 runners.

It was found that the best results were obtained from the runners and the worst from the weight lifters. The following Table shows the average ceilings for each group.

TABLE

AVERAGE PRESSURE-CHAMBER CEILING ATTAINED (in m)

Aleksandrov and Egorov (1939)

Runners	8333
players of various games	8220
weight lifters	8064
swimmers	8012
gymnasts	7859
rowers	7800
soldiers	7766
aviators	7714

What conclusions could have been drawn from these data? The most obvious inference might have been that the key to altitude tolerance lay not in systematic training to withstand reduced atmospheric pressure (anoxia) but in general physical training; otherwise the fliers, who had been systematically subjected to the effects of reduced partial pressure of oxygen, would have headed the list. In fact, however, the athletes came out at the head of the list, although their special skills had nothing whatsoever to do with high-altitude flights or high-mountain ascents.

Ordinary soldiers proved better able to tolerate high altitudes than did the fliers - a further striking proof that the systematic training to withstand moderate hypoxia, compulsory for all fliers, did not help to develop any adaptive mechanisms enabling them to withstand higher degrees of oxygen deprivation. This meant that general physical training rather than specific "hypoxemic training" was the main factor and that the type of sport in which the training was acquired did not matter much.

These were the conclusions one might have thought would be drawn, but, obvious though they were, Aleksandrov and Egorov continued talking about the importance of hypoxemic training, based on a definite program involving use of the AE apparatus, in addition to general physical training. They continued to express these views in other works.

Egorov, who had been occupied for many years with the problems of training and adapting the flier's organism to altitude, could not but tackle the question of physiologic adaptive mechanisms in earnest. He first expressed his opinion on this process in a paper entitled <u>An experiment in studying the adaptability of the organism to reduced partial pressure of oxygen</u> (1939a); but the view he expounds here differs little from any of the well-known opinions of Barcroft on adaptive mechanisms.

He expresses his own ideas more definitely in another paper, The effect of hypoxemia on the blood circulation and hematopoiesis (1941), where he states that "there is a definite pattern and sequence in the adaptability of the organism" and distinguishes "three degrees or three basic stages" in the process of "elaborating acclimatization". "In the first stage adaptability is attained primarily through intensification of the blood circulation functions, in the second stage through intensification of hematopoiesis and in the third stage through modifications in the intermediate metabolism". These "degrees" or "stages" in fact differ very little from Barcroft's "degrees": Egorov has merely eliminated for some reason the role of hyperventilation, which according to Barcroft is the first degree of acclimatization.

It was mainly Egorov and Aleksandrov who undertook work on the "first degree", that is, studying the intensification of the blood circulation, while Farber and Kudrin studied the intensification of the hematopoietic functions. The latter's thesis on the adaptability of the organism to a rare atmosphere (1940b) is an attempt to study the mechanism of the human organism's adaptation to altitude through systematic but brief pressure-chamber ascents. The tests were made on 9 subjects who remained at an altitude equivalent of 5000-6000 m in the pressure chamber for one hour.

These tests showed that compensatory mechanisms which helped the subject to withstand altitude did in fact develop as the result of such systematic ascents. The improvement took the form of better adaptation of the cardiovascular system, an increase in the respiratory surface of the blood due to intensified erythropoiesis, clearly expressed after 10 ascents, modifications of the urine reaction in the alkali direction, reduction of the urine ammonia and free acid increase of the urine pH, heightened efficiency and neuropsychic stability and a general improvement in feelings of well-being.

On the basis of these results Kudrin concluded that this kind of training - systematic "ascents" in a pressure chamber - could be effective. A series of questions, of course, immediately arose: how long must the training last? to what "altitude" must the trainee be raised? at what intervals must the "ascents" be made? what index could be used to measure progress? how long could the acclimatization mechanisms remain active? and so forth. Kudrin unfortunately left all these questions unanswered, merely remarking that "period pressure-chamber ascents" were "indicated" for fliers required to fly at high altitudes, but that the program for this training would have to be worked out later.

To sum up all these persistent attempts to solve the problems of training and adapting the organism to oxygen deficiency, which were urgent at the time, it must be admitted that these problems were not finally solved. While Vladimirov and Sirotinin did establish the effectiveness of high-mountain ascents as a method of improving altitude tolerance, Egorov and Aleksandrov did not succeed in demonstrating the efficiency of their AE apparatus for this purpose. Farber and Kudrin demonstrated the effectiveness of systematic pressure-chamber ascents, but the acclimatization effect was achieved only after many ascents (about

10) or a stay of many hours at high altitudes. This greatly reduced the possibility of using the pressure chamber as a training method. In regard to altitude tolerance in general, Egorov and Aleksandrov did succeed in showing that general physical training was the most important factor.

Physiology of the vestibular apparatus and determination of E. N. T. standards of fitness for flying. The physiology of the vestibular apparatus in a flier and the determination of his otorhinolaryngological suitability for the work was the second major problem on which Professor Voyachek's department worked for many years. An immense number of papers published by members of the department between 1925 and 1941 dealt with many aspects of the physiology and clinical picture of these organs. These papers were for the most part distinguished by profound theoretical treatment of individual question and by an attempt to apply the theoretical results in practice. The department was responsible for working out all the basic postulates on aircrew examination from the E. N. T. point of view, on training the vestibular apparatus in fliers, on the pressure function of the ear, of the effect of linear and radial accelerations on the vestibular apparatus and of the adverse effect of certain factors in flying on the otorhinolaryngological organs. All this represented a very rich contribution of Soviet aviation medicine. The department worked as a unit, making a combined frontal attack on the theoretical and practical problems requiring elucidation. Here we find none of the disunity evident in certain other departments; no one felt isolated when working on some problem by himself, but the whole team functioned as a closely-knit unit in which every member knew he had the support and interest both of his chief and of his colleagues.

Another very important point was that the testing and selection techniques worked out by the Voyachek school never ossified into a fixed canon. On the contrary, as the experimental work expanded and new data based on practical flying experience accumulated, these techniques and systems were constantly revised, subjected to deletions or additions and gradually but steadily improved.

The principal questions on which Voyachek's school worked were the vestibulometric selection of aircrew personnel, study of the ventilation capacity of the Eustachian tubes and prophylaxis against noise trauma.

Vestibulometric aircrew selection. The first attempt to determine labyrinthine standards for fliers was made by Khilov (1925, 1926). Khilov, who was thoroughly familiar with the theoretical ideas of his teacher, Voyachek, on the physiology of the vestibular apparatus examined 262 fliers with the aim of "determining the effect of flying service on the function of the cochlear and vestibular apparatuses". He used the Bárány chair test, taking the duration of nystagmus as the index to the vestibular function. Of the 262 subjects 138 were young fliers with two years' service and 124 had a longer service record. In 45 of the 138 young fliers of nystagmus lasted more than 20 seconds and in 23 less than 20 seconds. In 90 of the 124 older fliers the duration of nystagmus was more than 20 seconds and in 34 less than 20 seconds. On the basis of these data Khilov formulated the original but improbable conclusion that flying "made the

vestibular apparatus more sensitive to a physiological stimulus, namely, rotation". In his later work he radically altered this view but the first attempts to lay down labyrinthine norms for the flier led him to the conclusion that "the ideal flier was a man in whom the duration of post-rotational nystagmus was long and accompanied by only slight vegetative and somatic disorders".

It must be said that this conclusion immediately encountered opposition on the part of Osetrov (1927), who, on the basis of his own data from examining fliers, had reached the conclusion that brief nystagmus accompanied by poorly-expressed vegetative and somatic disorders were the characteristics of a good flier.

The question remained open until in 1927 Voyachek published his monograph The present state of our knowledge on the physiology and clinical picture of the vestibular apparatus, where he dealt exhaustively with theoretical and practical questions connected with the physiology of the vestibular apparatus. Speaking about its importance in spatial perception, Voyachek said that man possessed several apparatuses for the spatial sense, namely vision, the muscle-and-joint sense, hearing and, lastly the vestibular apparatus. In regard to the motion of an aircraft, to which the vestibular apparatus reacted, Voyachek distinguished circular motions with deceleration or acceleration and linear motions in the horizontal, vertical and combined directions, also associated with acceleration or deceleration. Analyzing all these aircraft motions from the standpoint of their effect as stimuli of the vestibular apparatus, he concluded that angular acceleration was the appropriate stimulus to the semicircular canals and gravitational acceleration the appropriate stimulus to the otolithic apparatus. This was the first time attention had been drawn to the reversal of rotation illusion, which is extremely important in flying.

Here Voyachek made a major contribution to aviation medicine, for this was the first comprehensive account of the role of the otolithic apparatus in flying. Previous ideas about the functions of the vestibular apparatus had been restricted to functional investigations of the semicircular canals; post-rotatory nystagmus was, of course, a clear index to this function.

It had become obvious that the mere fact of rotation in the Bárány chair stimulated the semicircular canals but left the otolithic apparatus, which was of paramount importance in flying, completely unaffected.

Kulikovskii saw the point very clearly (1930). He became convinced that, on the one hand, there was no correlation whatsoever between the duration of the post-rotational nystagmus and fitness for flying and, on the other hand, that the Bárány test often failed to reveal "latent proclivities to disorders of the vestibular apparatus". He therefore believed that if tests were confined to the Bárány chair the inescapable conclusion would be that "the vestibular function of the labyrinth did not have the exceptional importance attributed to it throughout the history of aviation". This made him insist on the necessity of introducing new tests.

One such test, of immense importance in the selection of Soviet aircrews, was the "double-rotation test" suggested by Voyachek in 1927.

After verifying and analyzing the results of the practical use of this test, Khilov (1929) concluded that there was a functional connection between the otolithic apparatus and the semicircular canal system and that stimulation of the former inhibited the nystagmic reflex of the latter. He believed that the reactions of falling or slipping and also the vegetative reactions, depended not on stimulation of the semicircular canals but on stimulation of the otolithic apparatus and that it was imperative to include the otolithic reaction (OR) test in aircrew selection examinations. He described in detail how this could be done and recommended distinguishing poor, medium and strong reactions.

The OR test won rapid recognition among the immense majority of aviation doctors. The system devised in Voyachek's department was adopted by the Air Force and made compulsory in examining aircrews. A complete examination technique was described by Kulikovskii in the appropriate chapter of the book Medical examination of aircrew personnel and candidates for admission to Air Force flying schools (1929).

Despite the apparently complete approval of the OR test in E.N.T. circles there seem to have been some people who did not quite agree with the propositions underlying its adoption. This is obviously the reason why Voyachek wrote his paper on The significance of the aural function and its pathology in military medicine (1932). Here he asked "whether the vestibular apparatus was or was not necessary in piloting an aeroplane" and answered that: "under more or less calm flight conditions the vestibular apparatus is not much involved" and "does not play much part in the pilot's work". Further, it "can never come to the flier's rescue" when he is flying in darkness or clouds; but its role becomes more appreciable "during the rapid run-in on coming in to land, during ejection by caterpult and in flying in bumpy air" as well as under certain other conditions. In these cases, owing to over-stimulation, the vestibular apparatus "becomes a force for loss of equilibrium". Therefore, "in selecting pilots it is essential to be able to evaluate their vestibular tone". Since vertical linear displacements, acting directly on the otolithic apparatus, stimulate the vestibular apparatus more strongly than anything else, the OR test had been introduced. Voyachek agreed with the views of certain otolaryngologists and fliers who pointed out that there was a great difference between the sensations occurring in actual flying and those produced in the OR tests; he himself admitted that "our ordinary laboratory stimuli are in many ways not identical with those which affect passengers in an aircraft; nevertheless, they did have much in common. The OR test made it possible to investigate both functions of the vestibular apparatus simultaneously and to shorten and simplify the examination.

Voyachek's views were later developed by Khilov (1933a). He again raised the question of the importance of the vestibular apparatus in aviation and after discussing in detail the mechanical forces operating on the flier performing advanced aerobatics, answered this question on the basis of experiment. He had

made a series of tests with a chair rotating in various planes, with a centrifuge and with four-bar swings designed by himself, and reached a number of interesting conclusions. He found that the vegetative reactions occurring as the animal's body moved remained almost the same even if the labyrinths were destroyed. A similar picture was observed when the animal was rotated in the centrifuge. Khilov inferred from this that "the vestibular apparatus in the presence of centrifugal force does not fulfil the physiological function of an orientating organ; under heightened stimulation it can act as a disorientating apparatus, upsetting the pilot's precision".

Khilov thought that the real reason for air sickness was displacements of the aircraft in the vertical plane. These provided a sufficient stimulus to the otolithic apparatus; accompanying stimulation of the semicircular canals "exceeded only slightly, if at all, the stimulation threshold". This was elegantly demonstrated by tests on animals with the four-bar swings. But tests on decerebrated and delabyrinthized animals convinced Khilov that the vegative component of the reaction was retained even after extirpation of the labyrinths and that therefore stimulation not only of the otolithic apparatus but also of the "mobile internal organs" were important in producing vegetative reflexes during the rolling of an aircraft.

Khilov expounded his point of view in greater detail in another paper (1933b), stating unequivocally that: "in piloting an aircraft the most strongly operative stimulus is not angular acceleration, which is the specific stimulus for the semicircular canals, but linear forces acting on the otolithic apparatus. These forces elicit not somatic but vegetative reactions and then only if the stimulation is cumulative; the manifestation of the vegetative reflexes is due not only to the otolithic apparatus but to the other proprioceptors as well".

Recognizing that, despite selection, some people with heightened sensitivity of the vestibular apparatus would become pilots, Khilov recommended vestibular training, but only "in regard to the otolithic vegetative reflexes". Such training could be either active or passive. He classed as active training all kinds of circular movements of the body, exercises on parallel and horizontal bars, walking on logs, climbing along the edge of a rotating prism, slow bicycling, exercises on the Ferris wheel, diving and skiing down mountain slopes and ice runs. Passive training included work with the centrifuge, merry-go-round, "devil's wheel", "rotation-bench" and four-bar swings.

In putting forward these suggestions Khilov admitted that their adoption might yield positive or negative results, that it was impossible to lay down any definite standards for training time and that the question of individual approach remained open.

He had not, however, based his suggestions merely on the results of laboratory experiments with animals and people, but had personally made a series of flights in which he performed aerobatics and carefully analyzed his own sensations and reactions. In the light of these personal observations he

expressed himself strongly in regard to the so-called Coriolis accelerations, to which many foreign investigators were attaching too much importance: "During a spin, a deep turn and a loop I inclined the head or the head and trunk in the direction perpendicular to the plane of rotation of the aircraft. In none of my experiments did I feel the sensation of reversal of rotation or of falling, nor did the vegetative reflexes appear. The only time I experienced vestibular reactions was during continuous maneuvers lasting 40-60 minutes, and then only in the form of a vegetative syndrome. The tests in the air have convinced me, first, that the typical vestibular reactions which we usually obtain the laboratory ... do not occur during aerial maneuvers and, secondly, that only during prolonged maneuvers (that is, when the stimulations accumulate), and then only in subjects with heightened sensitivity of the vestibular apparatus, can an exclusively vegetative syndrome appear" (1934b).

The reason for the discrepancy between the laboratory data and actual flying experience lies in the centrifugal force acting on the pilot and inhibiting the vestibular effects. "The pilot, in maneuvering, finds himself outside his normal orientation and as he loses his normal vertical under the influence of centrifugal force, a new line, the direction in which the centrifugal force is operating, becomes his physiologic vertical", writes Khilov. "The flier is cut off, as it were, from his former spatial relationships and the aircraft becomes for him the center of space ... summing up, we can say that in aerobatics the effect of Coriolis forces and other stimuli acting on the vestibular apparatus does not take the form of the normal labyrinthine somatic reflexes".

While recognizing that in aerobatics, when centrifugal force is in play, "the vestibular apparatus does not have the significance of an important orientating organ", Khilov believes that in simple flight, particularly during blind flying in fog or at night, "the vestibular apparatus can be one of the most important orientators, and then its heightened excitability is even desirable". For blind flying, therefore, "...we must select people who would be extremely sensitive to a variation in the aircraft's position and to its motions, that is, would have the most pronounced vestibular stimulation threshold" but this heightened excitability of the vestibular apparatus must be expressed not as vegetative but as somatic reflexes.

Khilov's idea that people with heightened vestibular excitability should be selected for blind flying was, of course, erroneous. Aviation doctors did not take this line and Khilov himself makes no further reference to it.

He summarized all the views he had put forward in individual papers in a long article in the Journal of Ear, Nose and Throat Diseases for 1933-1934 and also in the first volume of the Central Psychophysiological Laboratory's 1936 Symposium. Here he first formulated the basic propositions concerning the cumulative method of studying the sensitivity of the otological apparatus and other proprioceptors to the effect of linear forces.

This entailed 15 minutes on the four-bar swings followed by producing the otolithic reaction (OR) first in the horizontal, then in the frontal and lastly in the sagittal plane. This was the only way to "foretell the subject's sensitivity to the accumulation of stimuli, that is, the vestibular qualities of the future flier... real validity cannot be claimed for any of the other clinical vestibular investigations".

The highlight of all the research done in this field by Voyachek's department during this period was Khilov's monumental work, Vestibulometry in aircrew selection (1936b), summarizing all the department's efforts to solve this complicated question throughout the ten years of its existence. The search had led to a definitive view on the functional significance of the semicircular canals and otolithic apparatus in a flier. The new OR technique of studying the functions of the vestibular apparatus had been introduced, the role of cumulative vestibular stimulations during flight had been established, a special instrument, the four-bar swing, had been designed for studying this effect and, lastly, it had become imperative to think about training the vestibular apparatus and possible to work out methods and schemes for such training.

All this was of great practical interest, and in the second half of the 1930s an immense number of investigations by aviation doctors, verifying and refining the propositions advanced by Voyachek's department, appeared in the Soviet literature.

In the department itself, however, interest waned. Voyachek himself continued studying these questions no less persistently than before, produced a brilliant monograph, Selected problems in military otolaryngology (1934) and designed in the department the first centrifuge for investigating the effect of radial acceleration. But the total amount of research done in the department on the problems of aviation medicine fell appreciably and there are no signs that creative work in this direction was resumed until after the war.

Ventilation capacity of the Eustachian tubes. Voyachek's department had always been interested in the problems of the flier's resistance to abrupt changes in atmospheric pressure. Back in 1926 Khilov had pioneered study of the tympanic membranes' resistance to reduced atmospheric pressure in the external acoustic duct and had shown that the maximum negative pressure that the normal tympanic membrane could withstand was 180-200 mm Hg. Later, Zasosov took up the problems involved in the pressure drops experienced by a deep-water diver (1927a).

These investigations enabled the department to start a serious study of functional disturbance of the Eustachian tubes, one of the main reasons for acoustic trauma in flying. Here it came up against the almost complete impossibility of advance diagnosis. This problem was solved in 1932, when Voyachek designed a special acoustic manometer with which not only local blockages, but also various degrees of functional insufficiency of the Eustachian tubes could be detected with great accuracy.

Parfenov (1934), after using Voyachek's acoustic manometer in a series of investigations under normal and pressure-chamber conditions, found it completely satisfactory for detecting blockages of the Eustachian tube and therefore concluded that its use must be made obligatory in selecting and examining aircrews.

Khilov (1935) supported this view and said that the selection of dive-bomber pilots and parachutists must be based on this principle.

The acoustic manometer technique was another valuable contribution to the careful selection of Soviet aviators, but for some obscure reason was not made obligatory.

Prophylaxis against noise trauma. The problem of noise trauma, which arose mainly in connection with propeller aircraft, lay within the purview of Voyachek's department for many years.

It had long been accepted by otolarnygologists that the prolonged effect of any kind of intensive noise was detrimental to the acoustic organ. Published data indicated that veteran fliers often suffered from impaired hearing. One of the earliest of these indications was given by Min'kovskii (1927), who examined 100 fliers with two to fifteen years' experience and found that the veterans had suffered lesions both of the sound-perceptive and of the sound-conduction apparatuses.

Kulikovskii (1930) held the diametrically opposite view and maintained that E. N. T. diseases of any kind were extremely rare in fliers. Where they were detected they had obviously either been present before the patient took up flying or had become manifest in people specially prone to these diseases as a result of the special circumstances of their work.

Khilov expressed approximately the same views (1935). He too recognizes that "if we carefully investigate the function of the acoustic organ in veteran fliers we cannot avoid noticing a clinical picture of acoustic disturbances in some of them", but on examining this phenomenon he finds that the whole point lies in the fact that resistance to acoustic trauma varies from one person to another. Cases of a proclivity towards deafness do undoubtedly occur, but this tendency can remain latent until such time as a strong or prolonged stimulus activates it. Noise can thus operate as an activator of potential deafness.

The department consistently upheld these views, expressed by its two principal members, and ignored the fact that this conception of acoustic trauma sometimes caused material hardship to a flier who had to abandon his profession because of impaired hearing.

To restrict the intake of people in whom the cochlear apparatus was potentially sensitive to flying the department suggested using the acoustic nerve fatigue test which had once been proposed by one of its members, Mitrofanov.

The test consisted in acoumetry before and after the subject was exposed to noise. In persons prone to noise trauma the fatigue effect was more pronounced than in those who were not. The method was not made obligatory in the examination of candidates.

Despite the above-mentioned views, Voyachek's department always believed that aviation noise could adversely affect the flier and therefore did its utmost to devise prophylaxis against deafness in aircrews. Trifonov (1934) tested various types of personal protective equipment (ear plugs, ear muffs) and found that the most suitable was Voyachek's ear plug. The idea of designing anti-noise equipment for fliers stimulated many aviation doctors and by the end of the 1930s a number of new models had appeared (invented by Kalmykov, Akopdzhanyan, Parfenov, Kulikovskii and others), until finally Popov succeeded in designing a new type of device, the "universal helmet", which obtained general recognition.

Reactions of the organism and traumatic injuries in parachuting

The Academy spent altogether only two years, 1932-1934, on these questions. The initiative was taken, not by the Academy but by the Red Army Medical Board, which instructed the Academy in 1931 to organize a special team for the study of the medical aspects of parachuting. The team consisted of Aleksandrov, Ivanov, Kabanov, Lebedinskii, Makarov, Lifshits and Skoblo.

Repeated examination of 41 parachutists before the jump, during a trial flight and after the jump revealed that every parachute jump entailed great emotional stress, causing heightened reaction on the part of the cardiovascular system, modification of the breathing (the breath was held during the jump and was abnormal just before landing), certain disorders of the higher nervous activity (disturbance of memory, slackening of attention, heightened rate of psychic reaction), hyperglycaemic effects, disorders of the renal function (in some cases protein and formal elements appeared in the urine). Comparing the reactions of parachutists after the first and after the fourth jumps the investigators concluded that the physiological reactions were far less acute after the fourth jump, as a result of training and habit. In these cases the emotional reaction was less pronounced, the reactions of the blood circulation were less acute, the performance of set tasks after the jump and the ability to maintain attention were improved and no cases of impaired memory were observed; in short, after the fourth jump the organism became completely resistant to parachuting.

On two test parachutists the investigators tried to find out how many jumps could be made in one day. They made the parachutists do three jumps in succession at half-hourly intervals. The results showed perceptible deterioration of the cardiovascular reactions, deterioration in the performance of tasks and the appearance of protein and formal elements in the urine. It was therefore decided to regard three jumps in succession as the "forced limit".

The general conclusion was that parachuting causes drastic emotional stress and considerable strain on the cardiovascular system. The degree of the latter is comparable to the strain induced by running with a load for 100 to 400 m. Since these reactions are temporary, however, the investigators concluded that the jump had no harmful effects on the organism whatsoever. Further, there was a positive aspect to parachuting in that it strengthened the will of the parachutist.

A natural continuation of this work was Gordon's research (1934). He set himself the aim of trying to objectivize the emotional disturbances accompanying parachuting. As the objective index he took the reflexes - the phenomena of oral automatism (the nasolabial reflex and the entire group of sucking reflexes). Unfortunately, he investigated too few parachutists to reach any definite conclusions, but some of his data are of undoubted interest. In 23 parachutists examined the day before jumping the phenomenon of oral automatism was noted in only 4.3 per cent, but in 25.8 per cent immediately before the jump; examination of the same subjects on the top platform of a parachute tower revealed the phenomenon in 41.8 per cent. As the number of jumps increased the curve perceptibly flattened out.

To counter the emotional distress felt by parachutists, Gordon (1934) recommended intensifying political and health education, making the parachutist thoroughly familiar with the technique of jumping, introducing training jumps from the parachute tower and paying greater attention to the neuropsychic sphere in selecting parachutists.

Makarov (1934) recommended introducing simple trips in the air as a supplementary method of discovering and training the flying aptitude of parachutists. He distinguished four types of response to this method: nervous excitability, fear and anxiety, symptomatic depression and mixed; the first of these was the commonest and people who responded in this way were the most easily trained. These types of response to ordinary flight were reversible and further flights improved the neuropsychic capacity for training.

A more extensive treatment of the parachutist's emotions appeared in a work by Gorovoi-Shaltan (1934). This author draws only one conclusion: evaluating the emotional behavior of a parachutist makes it possible to judge his willpower.

Isaev (1934) performed additional observations on the cardiovascular reactions accompanying parachute jumps in 18 subjects. His data confirm the team's results in regard to the blood-circulation reactions and the renal reactions. Among other things, Isaev believed that inflammatory processes in the kidneys or urinary tracts were inevitably aggravated by parachuting.

The interest of the Academy's therapists, neuropathologists, physiologists and psychiatrists in the problem of parachuting was confined to these works. The observations on the emotional experiences of parachutists, which had begun so interestingly but had been performed on a negligible number of subjects, were not continued.

Some surgical departments, too, showed a slight interest in the peculiarities of traumatism in parachutists and in the prophylaxis of these, but their interest was not sustained.

Geselevich (1933), working on the problem of surgical contraindications to parachuting, confirmed that it was right to weed out people suffering from varicose veins in the lower extremities, hernias and bandy leg. He also pointed out that people with the flat-footed, brachymorphic type of body constitution, people who had suffered malleolar or tarsal fractures, people with an anemesis of dislocation of the large joints, sufferers from arthritis, lumbago or memiscal lesion and people with enlarged spleen due to malaria were unsuitable. He did not recommend that people under 20-21 years of age or middle-aged people should perform parachute jumps.

Lastly, Shatskii (1940) discussed 51 cases of various traumatic lesions in parachutists. He drew attention to fractures of the hip, which often occurred in the median third of the diaphysis and were oblique or spiral in form.

Aerial evacuation

The problems of using aircraft for evacuating sick and wounded aroused comparatively little interest in the Academy. Doctor Bogoyavlenskii had written a short article on this subject in the Academic journal Nasha Iskra in 1926, but this did not stimulate any member of the Academy to make a more thorough study of this potential use of aircraft in a future war.

Nothing appeared in print until 1934-1935, when Petrov and Goncharov, of Professor Anichkov's department of pathophysiology, published an experimental study on the question of the altitude at which it would be possible to evacuate various types of wounded by air (Petrov and Goncharov, 1934, 1935a and b).

These investigators were interested to find out how animals (rabbits and dogs) would withstand reduced atmospheric pressure after suffering various wounds to the cranium, liver or muscles, after the formation of defects in the abdominal wall, after pneumothorax, or when emphysema was present or after abundant blood-letting. The experiments were performed partly during actual flight at various altitudes, partly by "raising" the animals to 6200-6700 m in a pressure chamber.

Cerebral prolapses with punctate hemorrhages and cyanotic coloration were observed in animals with cranial wounds (defective cranial bones, lesion of the dura mater) at altitudes above 3000 m. At lower altitudes these effects were much less pronounced. Compression bandaging noticeably helped to prevent the development of prolapsus.

In animals with wounds and defect of the abdominal wall ascent to 3300 m produced prolapsus of the intestine and momentum.

Acute dyspnea, which persisted for 30 minutes after landing, was caused in a dog with closed pneumothorax on one side on ascending higher than 3300 m. With open pneumothorax acute dyspnea set in at 2500 m.

With artifically-induced subcutaneous emphysema ascent to 1200 m caused perceptible enlargement of the emphysemic boundaries and dyspnea.

Blood-letting at the rate of 40 per cent of the total blood volume did not reduce tolerance of altitudes of the order of 6200 m, but if the hemorrhage reached 45-55 percent of total blood volume, only the first period after the blood-letting was likely to be very dangerous.

These data led the authors to conclude that men with cranial wounds could be evacuated at 3000-4000 m provided compression bandages were applied. Wounded who had suffered abundant loss of blood could be evacuated at this altitude too. The investigators did not give a conclusive answer in regard to the altitude at which it would be possible to evacuate men wounded in the abdominal cavity or the liver or suffering from wounds involving open or closed pneumothorax.

The conclusions they did reach, however, were undoubtedly very bold, particularly as in the majority of cases there was no need whatsoever to evacuate wounded in this category at such altitudes as 3000-4000 m.

Banaitis (1936a) had a completely different point of view. As a representative of the department of field surgery he first raised the fundamental point that aerial evacuation from the front could be only an auxiliary, not a basic method, except in mountainous or desert terrain.

He divided all wounded into four groups for purposes of aerial evacuation. The first group comprised those who had to be evacuated urgently, irrespective of altitude. The second group comprised those who must be evacuated urgently but not at altitudes above 1000 m. The third group comprised second-priority evacuees who could fly at any altitude and the fourth group those for whom aerial evacuation was completely contraindicated.

It is hard to find any fundamental objection to such a classification. The only term that gives rise to some misgiving is "irrespective of altitude", that is, at any altitude. There is no need at all to go so far in extending the "altitude limits" of evacuation aircraft. Experience shows that in the great majority of cases such aircraft fly very low.

Banaitis found himself in difficulties when he tried to make his classification more precise. He found that his first group (priority evacuation independently of altitude) would have to include those with initial manifestations of

tetanus, suspected cases of gas infection, cases of burns and frostbite, cases of injury to the eyes, face, vertebra, pelvis and pelvic organs as well as cases of injury to the upper and lower extremities and the major joints. Group four, for whom aerial evacuation was contraindicated, would have to include people with developed tetanus, acute oligemia, manifestations of collapse or shock and people wounded in the cranium, large joints, trachea, pharynx, esophagus, lungs, heart or with open or closed lesions of the abdomen.

Most of these indications and contraindications were controversial, and often ran counter to the experimental findings of Petrov and Goncharov. If the Academy had shown more interest, the controversial points could certainly have been cleared up; but the Academy lost interest in 1936, and no one tried to reconcile the Petrov-Goncharov experimental data with the quite different opinion of the department of field surgery.

Hygiene

The problems of ensuring hygienic conditions for aircrews was another matter in which the Academy showed little interest. But for Kalmykov's thesis on flying clothing and the two papers by Zimkin on the illumination of instrument dials (both written while he was working in the Aviation Medicine Section of the Air Institute of Scientific Research) it would have to be said that the Academy showed no interest at all in conditions of life and work for the flier while in the air.

Kalmykov's thesis (1934) consists of four parts: part 1 concerns the flier's working conditions, part 2 gives the results of hygienic evaluation of flying clothing as a whole, part 3 contains the results of investigating various fabrics used in flying clothing and part 4 suggests several types of improved clothing.

The author, taking into account flying conditions at the time, lists a series of requirements in flying clothing: the clothing must give good protection against heat and wind, must have minimum air permeability and low hygroscopicity, must be waterproof, soft and pliable, lightweight and not bulky, non-inflammable, resistant to oxidation-reduction, proof against oil and petrol, of simple design and suitable cut.

In the light of these considerations Kalmykov suggested several new types of flying suit, which were adopted by the Air Force. He suggested fur rather than the felt flying boots and introducing a new type of warm gloves, several types of mask to protect the face from frost and a new type of flying helmet.

The data he obtained while working on these problems provided material for a whole series of papers which he wrote while at the Institute of Aviation Medicine.

The works by Zimkin and Lebedinskii (1934) and by Zimkin alone (1936) on cabin illumination during night flights and on dial visibility have already been described above.

To this list must be added an article by Andrezen (1935) on the requirements to be satisfied by the glass in flying goggles. After critically examining a number of the glasses on the market, Andrezen recommended yellow Zeiss lenses as the best for flying goggles.

This was all the work the Academy did before the war on aviation hygiene research, unless we include an article by Ronchevskii on mental hygiene in selection of candidates for Air Force flying schools (1936).

On the basis of psychiatric examination of a group of students who had been rejected and another group who had good flying aptitude, Ronchevskii came to the following conclusions. Positive character traits for a flier were initiative, persistence, the capacity for intensive voluntary effort, thoughtfulness, cheerfulness, high vital tone, good general balance of the psychic processes, daring, resourcefulness and quick reactions. Negative traits were emotional excitability, instability, a tendency to exaggerated attitudes, nervousness, touchiness, tendenty to take offense, childishness, a scatterbrained temperament, slowness or excessive rapidity and jerkiness, unstable inclinations, poorly-developed capacity for voluntary effort, a tendency to be easily influenced, or, conversely, to be easily alienated.

Neutral characteristics - potentially negative characteristics which could be offset by positive traits - were impressionability, reserve, mild nervousness, moderately quick temper, general mildness of disposition provided the general psychic tone was good.

On this basis Ronchevskii urged that the psychiatrist should carefully examine all so-called expressive movements and gestures, for he believed that this was an important part of the psychiatric examination at the selection board.

Ronchevskii's views were not developed further or even subjected to practical test, nor, incidentally, were many other opinions, and the members of Osipov's psychiatric clinic very quickly lost all interest in these questions.

The most striking feature in the work of the Kirov Academy on the problems of aviation medicine during the period 1925 to 1941 is the great variety of topics which it touched on from time to time. This seems to have been due to lack of a broad approach. Individual departments, and often individual members of departments, undertook work on a particular topic, sometimes running

counter to the general direction of the department and completely unconnected with the general plan of research in the Academy, so that such works often give the impression of an episodic, random deviation from the department's main concern and from the work of the Academy as a whole.

Most of the departments engaged in a sort of gold rush. Some of them, fascinated when they struck paydirt almost at once, started digging deeper and deeper; others, for all their efforts, managed to find only a few nuggets and in their disappointment soon abandoned the workings they had started; still others, sceptical of the possibility of finding precious metal in this region, confined themselves to surface prospecting.

The overwhelming majority of the departments, abandoning aviation medicine, adhered to the third point of view and the characteristic feature of their work was inadequately sustained attention to the relevant topics.

The exceptions were Voyachek's E. N. T. department and Vladimirov's biochemistry department, which showed great persistence in working on extremely complicated problems and succeeded in rallying their members for sustained work on these problems over many years. The result was that they achieved outstanding results and made a most valuable contribution to Soviet aviation medicine.

It must be noted that some departments, which did tackle problems in aviation medicine seriously, gradually went deeper into the subject until it became their department's main direction of work. This applies mainly to the department of pathophysiology (Academician Anichkov and Professor Petrov).

Lastly, there were departments which had every possibility of developing research on aviation medicine but made inadequate use of these opportunities. An example was the department of normal physiology (Academician Orbeli).

In assessing the Academy's work on aviation medicine as a whole, it should be remembered that the pre-war years were the period when the Academy first started to work in this field. Research flowered only after the war, partly because of the tremendous impact of the war on the country and partly because of the exceptional role aviation played in the country's defense system.

THE ALL-UNION INSTITUTE OF EXPERIMENTAL MEDICINE (AIEM)

The All-Union Institute of Experimental Medicine started work on aviation physiology in 1934 and kept it up steadily until the outbreak of the Second World War. All the work was so arranged that the problems of anoxia were studied under laboratory conditions (pressure chambers, inspiration of oxygen-impoverished gas mixtures) and under conditions of high-mountain ascents. Some departments of the Institute even used aircraft flights for these purposes.

The following departments worked on anoxemia: the department of the physiology and pathology of the sense organs (Professor N. I. Graschenkov), the department of general physiology (Professor I. P. Razenkov), the laboratory of acoustic physiology and pathology (Professor L. A. Andreev), the laboratory of barothermophysiology (Professor M. E. Marshak), the laboratory of optical physiology (Professor N. T. Fedorov), the laboratory of experimental growth physiology and pathology (Professor I. A. Arshavskii and certain others). The high-mountain expeditions of the physiological team were led by A. P. Zhukov, those of the biochemical team by G. E. Vladimirov.

The most energetic work was done by the department of physiology and pathology of the sense organs and the department of general physiology.

In this section I shall describe the results of research done in the department of general physiology and in the laboratories under Andreev, Marshak, Fedorov and Arshavskii. The work of the high-mountain expeditions referred to above will be described in the next section.

The department of general physiology. The main direction of this department's work, under the distinguished scientist Razenkov, was study of the digestive processes under conditions of reduced atmospheric pressure. The efforts of the leading scientists in the section (E. B. Glikson, E. S. Zel'manova, M. M. Kogan, I. V. Malkinan, E. A. Mirer, V. A. Rubel', E. A. Rudnik, Yu. N. Uspenskii, S. I. Filippovich, I. M. Khazen, G. K. Shlygin, M. L. Eidinova and others) were devoted to experimental study of the secretory, excretory and motor functions of the alimentary tract.

Razenkov's aim was very broad. The plan was to study experimentally, first on dogs and then on human subjects, using the classic method of Pavlovian physiology, all aspects and peculiarities of the digestive processes under conditions of reduced atmospheric pressure. At the same time it was planned to study the processes of assimilation of basic nutrients, the biochemical processes and morphological changes in the various parts of the digestive system occurring under conditions of reduced atmospheric pressure. It was assumed that in the light of this all-round study it would be possible to devise a series of practical measures for rationalizing the diet of pilots, quite apart from solving a series of fundamental theoretical problems in regard to digestive physiology.

To this end the experimental work involved not only raising animals and human subjects to various altitudes in pressure chambers but also two high-mountain expeditions (1939 and 1940) and prolonged flights at various altitudes.

The first information on the results obtained were published in 1940 and the last in 1948. In the meantime members of the physiology department published 47 scientific papers, including Razenko's monograph Digestion at altitude (1945) and a separate symposium under his editorship (1948).

This sustained attention and effort lasting for about ten years bore fruit. A number of interesting new facts was discovered in regard to the digestive processes and their regulation under conditions of various degrees of anoxia and these results were of exceptional theoretical and practical value. It was found that both the secretory and the excretory activity of various glands in the digestive tract suffered a series of important changes under anoxic conditions; the motor function of the gastrointestinal tract altered too.

In dogs kept at 4000 m in the pressure chamber for a long period the salivary solution was reduced, the dense residue in the saliva was found to diminish, the urea and lactic acid levels rose and amylase, absent from the normal saliva, appeared.

These changes were not detected when oxygen was inspired at altitude, nor were any changes in the salivation detected when the animals were kept at altitude for a short time (up to 20 minutes). After a series of high ascents (9-10), changes of the salivation were either not recorded at all or were negligible (Filippovich, 1940a and b). Another factor affecting the modifications of the salivary gland activity at altitude was the nature of the stimulus: a repellent stimulus elicited more drastic modifications than did the food stimulus. Extirpation of the superior cervical sympathetic ganglion elicited more lasting changes in the salivary gland secretion and the adaptation of the salivary glands developed more slowly (Filippovich, 1948b).

Study of the activity of the salivary gland in dogs during high-mountain ascents did not yield such clear-cut results. Uspenskii (1940) found that at 2200 m the secretion "sharply diminished", but that at 4250 m it was greater than at the start. According to Rubel' and Khazen (1948), no variation at all was recorded in the secretion of one dog either at 2200 m or at 4800 m, whereas in another dog, after extirpation of the superior sympathetic ganglion, secretion was inhibited during the first days but restored later. At the same time amylase appeared in the saliva, the urea and lactic acid level rose and the sugar level fell.

During 2-3 hour flights at 3500-4200 m the salivary secretion in dogs diminished (Uspenskii, 1940).

When the salivary secretion was investigated in man (2 subjects) it was found to diminish towards the end of a 4-hour stay at 4000 m and to remain diminished for 2-4 days after the ascent. At the same time increased spontaneous salivation was constantly recorded. The solid residue in the saliva was observed to increase, along with its diastatic power. After repeated ascents the inhibition of the salivary gland activity disappeared. When oxygen was inhaled at 8000 m the secretion was reduced in one subject but intensified in the other (Filippovich, 1940a).

Three subjects were observed during a high-mountain ascent but the results were not identical. At 2200 m the secretion was reduced in two of them but

rose in the third. At 4250 m it rose in two of the subjects but fell in the third. Qualitative changes in the saliva took the form of increased sugar and urea content and reduced lactic acid content (Rubel' and Khazen, 1948).

Morphological investigations of the salivary glands in dogs after they had been kept at 8000 m revealed no deviations at all from normal apart from dilatation of the vessels, which became engorged with blood (Kogan and Rudnik, 1941).

The gastric glands. Investigation of the functioning of the gastric glands was performed on dogs with Heidenhain and Pavlov's stomachs.

The first tests on such dogs were made in pressure chambers at 6000 and 8000 m. The offering of such food stimuli as bread and hematogen led to a negligible reduction of the secretion in the dogs with Heidenhain stomach and abrupt inhibition of the secretion in dogs with Pavlov's stomach. Inspiration of oxygen at altitude caused these disorders to disappear. Qualitative changes in the gastric juice at altitude amounted to a rise in the urea and lactic acid levels (Zel'manova, 1940a).

Roughly similar results were obtained by Malkiman (1940), who recorded an increase in the solid residue in the gastric juice and increased acidity at altitude. The acidity question however, still seems to have been somewhat obscure, for Malkiman, in his 1941 paper, gives data showing that in dogs with a Pavlov stomach the acidity of the gastric juice was reduced both after a stimulus such as bread and after alcohol.

Inhibition of the gastric secretion at altitude apparently depends not only on the hypoxic factor but also on the nature of the food stimulus. Tests with various stimuli (bread, meat, hematogen, alcohol) on a dog with a Pavlov's stomach showed that the secretion was inhibited at 4500 m only in response to such a stimulus as bread but remained unaltered in response to any other stimulus (Malkiman, 1948); at 7000-8000 m, however, the inhibition set in in response to hematogen, plums and milk and was strongest when bread was offered. Conversely, it increased in response to histamine (Zel'manova, 1948).

All these data led Razenkov (1945) to the conclusion that "inhibition of the secretion of gastric juice under reduced barometric pressure is the result primarily of a disturbance of the nervous mechanism of secretion; the humoral mechanism is hardly disturbed at all".

Investigations were performed on three dogs with Heidenhain stomach during a high-mountain ascent. At 2200 m the secretion picture was varied: in one dog the secretion was reduced, in another it did not alter and in the third it increased.

Motor activity of the stomach. The first investigations on the effect of hypoxia on the motor activity of the stomach were made as early as 1938 in Strel'tsov laboratory, by Kruglyi and others (1938a), who established the fact

that the motor activity of the gastrointestinal tract was inhibited during a period at altitude.

Subsequent investigations in Razenkov's laboratory confirmed this finding. It was found that at 8000 m a distinct but not persistent inhibition of the periodic activity of the stomach did in fact occur in animals and that it was entirely dependent on the hypoxic factor, since inspiration of oxygen at altitude completely restored this activity (Eidinova, 1940b).

The biligenic function of the liver was disturbed in dogs under conditions of reduced barometric pressure. These disorders, occurring at altitudes between 6000 and 8000 m, took the form of abrupt and fairly persistent reduction of the biligenesis, the viscosity and dense residue content increasing. The quantity of bile acid and bilirubin increased but the cholesterin level fell. These changes tended to persist. Repeated ascents did not as a rule elicit adaptation effects (Glikson and Rubel', 1940b).

In mountain ascents to lower altitudes (4250 m), on the other hand, the bile secretion was found to increase while the bile acid level rose and the viscosity of the bile increased (Uspenskii, 1940). Glikson verified these findings in a pressure chamber by raising a dog to 4000-4500 m, when he again detected increased secretion of bile. During a second mountain ascent it was established that the bile secretion increased at only 2200 m (Rubel' and Khazen, 1948).

Morphological changes in the dogs' liver after several ascents to 8000 m were expressed as an abrupt dilatation of the capillaries accompanied by phenomena of compression of the hepatic trabeculae and vacuolization of the protoplasm in individual hepatic cells.

The pancreatic gland. No substantial alteration occurred in the secretion of the pancreatic gland during a mountain ascent to 2200 m but at 4250 m some inhibition of the secretion was detected.

Morphological changes of the pancreatic gland after dogs had been kept at 8000 m were expressed as a sharp dilatation of the vascular network, which became engorged with blood, swelling of the epithelium, homogenization of the protoplasm and pycnosis of the nucleus of individual glandular cells. Structural changes in the glandular lobes were negligible even after 63 ascents (Kogan and Rudnik, 1941).

The intestinal glands. At 6000-8000 m some reduction in the intestinal glands was caused in dogs with a Thiry's fistula but no substantial alteration in this respect was detected in dogs with a denervated intestinal loop. In these and in other cases, however, an increase in the dissociative power of the intestinal juice was noted (Khazen, 1940b). In mountain ascents the secretion increased at 2250 m and decreased at 5250 m in both groups of dogs. In flights at 3500-4200 m lasting 2-4 hours drastic inhibition of the secretions was observed in all the dogs accompanied by drastic reduction of the urea and diminution of the

amilolytic power of the juice (Uspenskii, 1940). Two-hour flights at 500-800 m again produced inhibition of the secretion but qualitative changes in the intestinal juice were negligible. Brief (30 minutes) flights in bumpy air caused drastic inhibition of the secretion (Uspenskii, 1948a).

Morphological changes in the small intestine, in the form of corrugation of the epithelial cells and pycnosis of their nuclei, were detected only after 15 pressure-chamber ascents to 8000 m.

Food assimilation. Experiments showed that dogs kept for 4-1/2 hours at 7000 m suffered no changes at all in the food assimilation but that it was somewhat reduced if they were kept at 8000 m for 5-1/2 hours daily for 3 days (Mirer, 1948). From this Razenkov concluded (1945) that the altitude of 8000 m had "practically no effect on assimilation of the principal foods".

In this brief account I have tried to set out the main findings reached by members of the department of general physiology. Razenkov's conclusions from them (1945) was that reduced barometric pressure "affected primarily aspects of the digestive process which are influenced to a comparatively great extent by the nervous system"; he continues, "but those aspects of digestion ... mainly influenced by the humoral regulations ... suffer to a smaller extent or do not change at all and in certain circumstances are even intensified" (p. 205).

At the same time, Razenkov made additional comments which greatly reduced the value of the basic conclusion. The neuroreflex influences, for example, were not "the sole physiological mechanism through which reduced barometric pressure influenced the organism" and humoral factors played a "no less important part". He was inclined to believe in a "relative autonomism of processes effected in the organs and tissues themselves", since "processes occurring in organs and tissues are relatively autonomic" (p. 206).

These additions to the main conclusion are difficult to reconcile with the principles of Pavlovian physiology and are due to a number of contradictions arising in the experimental study of the various processes. Data obtained in the pressure chamber by no means always correspond to the data obtained under mountain conditions, nor do the latter correspond to the results obtained in aircraft flights. Again, there are contradictions between the animal and the human data. A few conclusions based on investigating two or three animals and one or two human subjects, moreover, were certainly insufficient to affect the final conclusion.

Owing to these contradictions, Razenkov's difficulties in trying to formulate a number of practical conclusions as a basis for rationalizing the diet of fliers were inevitable. By adopting the basic theory that reduced atmospheric pressure affected the organism both "via the nervous system and through humoral factors and also by way of direct action on the organs, tissues and systems themselves", Razenkov had to confine himself to the recommendation that practical measures should be directed "along any one of these paths separately" (p. 207).

All the research done by Razenkov's colleagues undoubtedly had great theoretical importance and their value is not reduced by the presence of a number of contradictions in the experiments. The experiments themselves show that Razenkov was tackling a large, interesting and important question requiring further and more thorough experimental study. The factual material collected by his coworkers added a new page to altitude physiology and were of great importance to Soviet aviation medicine.

Other Departments of the Institute

The other departments, although less heavily involved in problems affecting aviation medicine, nevertheless did work of considerable interest, primarily because it was highly experimental.

In the laboratory of acoustic physiology and pathology Andreev and his coworkers Pakhomov and Yudina pioneered study of changes in the higher nervous activity in dogs subjected to anemic hypoxia of the brain. This was achieved by binding both carotid arteries. The consequent anoxemia of the cortical cells caused all previously-elaborated conditioned reflexes to disappear completely and they were not restored until two weeks had passed. Analyzing the disorder of the higher nervous activity in these cases Andreev concluded that "the disturbances affected the analytic activity (of the cerebral hemispheres) more than the synthetic activity" (1935).

It is a great pity that work so interestingly begun should for some reason or other have been abandoned.

The laboratory did return, later, to the problem of hypoxia but the work took the somewhat different direction of electrophysiology. In 1940 Shpil'berg undertook to study the muscular-activity currents under conditions of anoxemia. She found that when the oxygen concentration in the air was reduced to 11-10% the amplitude of these currents at first increased but later progressively diminished, the number of oscillations diminishing at the same time. She regarded this phenomenon as the result of depression of the central nervous system and proprioceptors due to oxygen deficiency.

Later (1944) Shpil'berg studied the cortical biocurrents in man under anoxic conditions. She took electroencephalograms of 12 men breathing an oxygen-impoverished gas mixture (9.0-7.78% of oxygen) but could detect no substantial variations until immediately before the onset of syncope, when she was able to detect a diminution of the alpha waves.

In the laboratory of barothermophysiology under Marshak extremely interesting work on the regulation of the breathing and blood circulation under conditions of hypoxemia and hypocapnia was planned. A team consisting of

Ardashnikova, Braitseva, Vereshchagin, Voll, Shik and Urieva started this work just before the war but no important experimental data were obtained then. The work was resumed on an expanded scale in the last years of the war and after the war.

Marshak, in his paper read at the 1939 All-Union Conference on Aviation Medicine (1940) had approached the topic of the regulatory processes by which the organism adapted to anoxia. He believed these reactions to consist in intensified respiration, contraction of the spleen, intensification of the cardiac activity, a rise in the blood pressure and a change in the blood supply to the individual organs and tissues. He distinguished two stages of adaptation, the first due to reactions of the central nervous system, the second occurring "in the peripheral organs and tissues, not by the reflex path but through the direct effect of insufficient tension of blood oxygen on the organs and tissues concerned".

Shik (1939), tracing the altitude-adaptation effects accompanying repeated inspiration of oxygen-impoverished gas mixtures found that the quantitative and the percentage oxygen demand were reduced during the first tests but that on repetition of the tests the fall in demand, both of oxygen percentage and of oxygen consumption, was smaller. This contention was developed in greater detail by Shik, Urieva and Braitseva (1940) and treated as proof of adaptation to hypoxia resulting from repeated brief inspiration of oxygen-impoverished gas mixtures. On the basis of data showing that the chemoreceptors of the carotid sinuses took part in the regulatory process during very slight hypoxemic effects, these authors concluded that such adaptive mechanisms as intensified breathing, intensification of the cardiac activity, a rise in blood pressure and contraction of the spleen were effected by the reflex path.

Marshak and Voll (1941) later showed that in hypoxemia the conditions of blood supply to the organs varied: the blood supply to the brain increased but the blood supply to the internal organs decreased. If 4-5% of carbon dioxide were added to the inspired air while hypoxemia was developing the blood supply to the brain increased still more but the supply to the internal organs increased as well; so too did the rate of blood flow.

Shik's investigations on the ratio between oxygen demand and oxygen tension are of particular interest (1948). This research corroborated the well-known fact that oxygen demand does not change under anoxic conditions. This was observed, however, only when the body temperature did not fall; if it did, the oxygen demand invariably fell also and the animal's resistance to hypoxia consequently increased. Rats died in air containing 4.5-4.0% of oxygen when the body temperature was 30°C, but if the body temperature was reduced they perished only when the oxygen level in the atmosphere was down to 2.5-2.0%.

Later, Shik greatly extended this research and put the results in final form in his doctorate thesis, Gas exchange in anoxia (1947). The research successfully started in the laboratory of barothermophysiology before the war was continued during and after the war in the department of respiration and blood circulation of

the All-Union Institute of Experimental Medicine, under Marshak, and the results were published in a symposium, The regulation of respiration, blood circulation and gas exchange (1948) containing much interesting new experimental material on the special character of the respiration and blood regulation in an altered external environment.

In Arshavskii's laboratory of experimental growth physiology and pathology work on the effect of anoxia was started in 1941. In the very first paper (Krasnovskaya, 1941) an attempt was made to demonstrate that neonates were more sensitive to lack of oxygen than adults. Adult dogs perished in air containing less than 4% of oxygen but puppies aged 16 to 18 days died even when the oxygen concentration was 14-15%. It was later established (Krasnovskaya, 1943) that no adaptive responses at all occurred in the breathing and blood circulation of such puppies under anoxic conditions, owing to the absence of the sinusial and aortal nerve functions in animals of that age. Arshavskii's discovery that the depressor effect typical of stimulation of the sinus nerve and characteristic in the adult animal did not occur in puppies until the 15th-18th day of life and that the typical effect of the aortal nerves was established only at the age of 1-1/2-2 months is well known (Arshavskii et al., 1943a).

Rozanova (1953) directly inferred from this that all previous research on the improved anoxia tolerance of neonate animals had been "methodologically wrong" and that tolerance was not higher but invariably lower than in adult animals. Arshavskii, verifying this on infants, found that their tolerance to hypoxia between the ages of 2 and 12 months was considerably lower than that of adults (Arshavskii et al., 1943b).

On the basis of these data Krasnovskaya (1943) rejected all inferences to the effect that resistance to anoxia was higher in neonate animals and Arshavskii and Rozanova (1949) stated that "we must categorically reject the notion that the young organism is more resistant to anoxia".

This view, be it said, was in sharp contradiction to the facts established by Ber (1878), Sirotinin (1938), Parfenova (1938b), Vaie (1940), Pal'gova and Volobuev (1940), Lauer (1949) and a number of investigators in other countries.

To summarize: the All-Union Institute of Experimental Medicine did very fruitful work on matters directly relating to aviation medicine. The immense amount of experimental data obtained constituted an exceptionally valuable contribution to the study of reduced barometric pressure effects, while the theoretical pronouncements of the leading Soviet physiologists on a number of theoretical and practical questions greatly enlarged current ideas about the role of the central nervous system in regulating the basic physiological compensatory mechanisms in hypoxia.

Owing to the war it was unfortunately impossible to publish all these new data and they remained unknown to the great majority of Soviet aviation doctors.

ESSAY VIII

CONTRIBUTION OF SOVIET MOUNTAINEERING PHYSIOLOGISTS TO AVIATION MEDICINE

1

The vigorous development of Soviet aviation in the 1930s brought to the fore the old but still not fully solved problem of how the human organism responds to reduced atmospheric pressure. A number of research institutions now started systematic pressure-chamber experiments and tests on the effect of inspiring oxygen-impoverished gas mixtures. These investigations did not always produce results, for the duration of the observations—a few tens of minutes or at most a few hours—was too short. Yet there was increasing practical need for more thorough investigation of the problem and investigators were constantly being faced with new, hitherto untouched problems.

One of the most urgent concerned the acclimatization and adaptation of the human organism to reduced atmospheric pressure. By the beginning of the 1930s a series of contradictory, often mutually exclusive hypotheses about the mechanism of altitude acclimatization had built up in the literature published abroad, but they merely confused the essence of the problem. There was the theory of active oxygen secretion by the pulmonary epithelium; there was the theory of heightened diffusion capacity on the part of the pulmonary alveola; there were theories about shifts of the oxyhemoglobin dissociation curve, about the special role of hemoglobin in improving the respiratory function of the blood, about the special role of muscular hemoglobin; lastly, there was the theory of tissue acclimatization. There were so many contradictory theories that it became essential to conduct new experiments, based on the principles and methods of advanced physiology.

The solution of the altitude acclimatization problem proved vital to Soviet aviation medicine; without it no-one would have seen the point of the pressure-chamber training which became firmly established in Soviet aviation during the 1930s.

Another, equally important question, which could not be solved by pressure-chamber experiments or by tests based on inspiring oxygen-impoverished gas mixtures, related to the effect of slow but prolonged reduction of the oxygen supply. This did not seem particularly urgent for aviation medicine, for in flying, hypoxia sets in quickly and does not last long; but it was

highly topical from the clinical point of view, for the slow onset of prolonged hypoxia was a common phenomenon in clinical medicine.

A third question, of equal interest to aviation physiology and to clinical medicine, concerned the prolonged effect of slight hypoxia on the human organism. The aviation physiologists were inevitably interested mainly in the effect of repeated, systematic slight hypoxia, but that question could not be solved until the fundamental question of the effect of prolonged slight hypoxia had been settled. The right answer to this question was undoubtedly of exceptional importance to clinical medicine.

The aviation medicine research institutes could not hope to solve all these complicated physiological problems with the resources at their disposal. Instead, a whole series of high-mountain expeditions by physiologists was organized. The results made an exceptionally valuable contribution to Soviet aviation physiology.

I do not suggest that the progress in aviation and the urgent problems facing aviation medicine were the factors mainly responsible for the development of high-mountain physiology. They certainly played a part, but the decisive factor was that in the 1920s the general problem of anoxia had become important in Soviet physiology and clinical medicine. Clinical practice has shown that anoxia played an extremely important part in the course of an immense number of diseases and pathological conditions due to various poisons, including war gases, and that the consequences of ignoring or underestimating this in treating respiratory or cardiovascular diseases were often fatal. The results obtained from the new oxygen therapy were striking proof of this.

It was therefore natural for Soviet physiologists, faced with the old but still unsolved and widespread biological problem of anoxia, should put a great deal of effort into solving it. The research done by means of high-mountain ascents from the late 1920s to the outbreak of the Second World War was a valuable contribution to Soviet biology, physiology and clinical medicine.

The aviation physiologists made extensive use of these results, rightly regarding the study of mountain hypoxia as no less valid a method of studying the effect of reduced atmospheric pressure than the pressure chamber or oxygen-impoverished gas mixture techniques.

2

The success of the expeditions owed much to the development of mountaineering in the Soviet Union. The tradition had started in Russia in the nineteenth century and was associated with the investigation of mountain regions by such eminent Russian explorers as Przhevalskii, Kozlov, Mushketov,

Semenov-Tyan'-Shanskii, Severtsev, Pastukhov and others; but it was only after the Revolution, mainly in the 1930s, that mountaineering became general.

A characteristic feature of Soviet mountaineering is its popularity. In 1929 training camps were started, enabling large numbers of people to make ascents together. The Red Army, the Central Council of Trades Unions and other organizations organized remarkable alpiniads. In 1933 only 58 people had reached the top of Mount El'brus, but in 1934 276 people and in 1935 2,016 climbed to the summit. By 1940 there were 36 high-mountain camps, catering for 12,000 people during the summer.

Physiologists took part in a great many such expeditions. Some of the most remarkable were the expeditions of Bykov, Vladimirov, Zhukov, Sirotinin and a number of other eminent physiologists. The complete list is too long to give here, but in terms of results the following were the most remarkable:

1926 Expedition of the Institute of Experimental Medicine: London, Kochneva, Rabinkova, with Abderhalden, Loewy, Roske, Rosener and Wertheimer at Davos (1559 m) and Muotar-Muregl (2450 m). Bykov-Martinson expedition, Shidzhatmas (2100 m).

1930 Second Bykov-Martinson Shidzhatmas expedition.

El'brus expedition of the Kazan' Medical Institute department of pathophysiology, led by Sirotinin (5595 m).

1931 Second Sirotinin expedition, Alai heights.

El'brus expedition of the Institute of Health Resorts: Gorinevskaya, Kalinovskii, Krestovnikov and others.

1932 Third expedition of the Kazan' Medical Institute's department of pathophysiology and the Health Commissariat's Medico-Biological Institute to the Kazbek, led by Sirotinin.

1933 Fourth expedition of the Tatar Commissariat of Health and Kazan' Medical Institute department of pathophysiology, led by Sirotinin, to the Trans-Alai ridge.

Red Army alpiniad, El'brus. Physiological investigations by Shatenshteyn, Chirkin, Kosyakov and Kotov.

1934 Joint expedition of the USSR Academy of Sciences and the All-Union Institute of Experimental Medicine, El'brus.

Physiology team led by Zhukov, biochemistry team by Vladimirov. Kazbek expedition led by Sirotinin.

1935 Second joint El'brus expedition: Vladimirov.

El'brus expedition of the Ukrainian Academy of Sciences and the Ukrainian Institute of Experimental Medicine, led by Sirotinin and Shamov.

1936 Third joint El'brus expedition (USSR Academy of Sciences, All-Union Institute of Experimental Medicine, Kirov Medical Academy) led by Vinogradov.

Tien-Shan expedition, Sirotinin and Fazlulin.

1937 Fourth joint El'brus expedition, Vladimirov.

Azerbaidzhan high-mountain expedition, led by Sirotinin Pamir expedition of the Central Institute of Nutrition.

1938 Fifth joint El'brus expedition, Vladimirov.

Kazbek expedition of the Kiev Institute of Labor Hygiene and Physiology, led by Sirotinin.

1939 Sixth joint El'brus expedition (with third Leningrad Medical Institute), under Vladimirov.

Gissar expedition of Ginetsinskii and Barbasheva.

1940 Seventh joint El'brus expedition (again with the third Leningrad Medical Institute), under Vladimirov.

The above list by no means covers all the research done by physiologists in high-mountain regions, nor does it include the names of all those who worked on the problem of reduced atmospheric pressure. This is because a great many of the expeditionary results were never published and some of the conclusions remained in manuscript form. But the list is adequate to give a clear picture of the work done.

To attempt a critical review of all this ambitious work would involve special research. The following account therefore covers only the work and results of the main expeditions before 1940.

3

As London's ascent (1926) was chronologically the first it deserves special mention. The expedition was jointly organized by the department of general pathology of the All-Union Institute of Experimental Medicine, the

Halle Physiological Institute and the Davos Institute of Mountain Physiology, and therefore consisted of London and his co-workers Kochneva and Rabinkova on the one hand and of four German scientists headed by Abderhalden and Loewy on the other. This greatly affected the character of the expedition, for the Germans had before them a fixed ideal in the great ascents made by Zuntz, Loewy, Müller and Caspari twenty years earlier (in 1906) and they were anxious to follow exactly the same path as these authors had mapped.

A novelty in the work was the new method of angiostomy invented by London, with which the organizers hoped to obtain interesting new data. With this technique blood could be taken painlessly from a dog, from such veins as the portal, hepatic, lienal and adrenal veins and in sufficient quantity (some tens of cc) for a wide range of investigations. It was proposed to use this technique for studying changes in the blood in the superficial and deep vessels while the animal was at high altitudes. The investigators aimed at studying changes in the red and white blood, hemoglobin level, color index, pH, blood gases, blood viscosity, water content in the blood, alkali reserve and sugar, calcium, potassium, phosphorus and chlorine levels in the blood.

London operated on a number of dogs before he left Leningrad and took these to Halle. Angiostomy was performed on the portal, hepatic, lienal, renal and adrenal veins.

The results were published in a short article in Pflügers Archiv in 1927 (Vol. 261, No. 3) which contained a great many tables and very little text and left the impression that the authors were dissatisfied both with the results and with the angiostomy technique. London's own attitude to the results remains unknown, for the Russian literature contains no information about the expedition.

The main conclusions which the investigators reached as a result of their experiments at Halle (78 m), Davos (1559 m) and Muotas-Muregl (2450 m) can be summarized as follows: 1) the erythrocyte count increased during the ascent and fell during the descent; 2) at altitude an exitus of erythrocytes from the spleen was observed; 3) true erythropoiesis was observed during a prolonged stay at high altitude; 4) the erythrocyte dissolution count seems to have fallen at altitude; 5) the leucocyte count fell at altitude; 6) the blood viscosity increased at altitude, that of blood taken from deep veins being higher than that of blood taken from superficial veins; 7) the total blood count at altitude neither increased nor diminished; 8) the liquid content of the blood diminished at altitude; 9) the blood pH remained constant; 10) the alkali reserve diminished; 11) the blood-sugar level remained constant; 12) the blood potassium level first fell, then fluctuated above and below normal; 13) the blood calcium level fluctuated too; 14) the phosphorus level rose.

The mechanisms underlying the effects do not seem to have been clear to the authors, for they confined themselves to giving the factual data without discussion.

4

The two Shidzhatmas (Kabardino-Balkar ASSR) expeditions in 1929 and 1930 were of incomparable importance for the study of physiology responses to a high-mountain climate. These were the first mountain ascents for physiological research purposes. The data related to only two men and several dogs at the comparatively low altitude of 2100 m, but were so interesting that it became clearly necessary to organize a whole series of further expeditions. Bykov's and Martinson's articles (1933) summarizing the results of the two expeditions give a comprehensive picture of the effect of reduced atmospheric pressure on the organism at several altitudes. The purpose of the subsequent expeditions was to study the physiological effect of higher altitudes; in regard to low altitudes, the results of these expeditions amounted merely to refining certain details and some of the propositions advanced by Bykov and Martinson.

The main purpose of the expeditions was "to study the general physicochemical behavior of the organism" under conditions of reduced atmospheric pressure. This was to be done by carefully studying "the energetic condition of the organism at rest and in action" and the "acid-alkali ratios in the organism". The final aim of the investigations was to discover the mechanism of the human organism's adaptation to reduced atmospheric pressure, but it was most important to solve the large and complex biological problem of "the influence of rare atmosphere on the human organism".

The expedition's carefully drawn up plan for comparative investigation on the two members of the team at Leningrad, Pyatigorsk (510 m) and on Mount Shidzhatmas (2100 m). In addition, investigations were to be made on dogs with exposed ureters, subcutaneously exposed spleen and Pavlov stomachs.

It was established that at 2100 m the oxygen demand increased, pulmonary ventilation intensified and the CO_2 evolution, respiratory quotient and frequency of respiration increased. It was therefore concluded that "the basal metabolism noticeably increased at an altitude of 2100 m". Study of the gas exchange during a functional test, however, showed that the oxygen demand then increased still further: "pulmonary ventilation, oxygen expenditure and CO_2 evolution was 100 per cent higher at 2100 m than in Leningrad". The inference from this was that any "work performed in the mountains, even at 500 m, calls for a large oxygen consumption" and that the basal metabolism increased at altitude.

Special attention was paid to the gaseous composition of the blood and the acid-alkali balance. Investigations of the venous blood in the men showed that the carbonic acid level and consequently the alkali reserve, fell at altitude, along with the oxygen content of the blood. The urine investigations yielded inconsistent results: in one of the men the ammonia level, total acidity and

organic acid level in the urine fell slightly, but in the other the same components showed an increase. The amount of inorganic alkalis in the urine of both men, however, increased at altitude. The investigators concluded that no clear signs of acidosis could be detected at altitude but that the increase in inorganic alkalis in the urine rather pointed to compensation of alkalosis due to hyperventilation.

Investigation of the arterial blood in the dogs also showed reduced oxygen and CO_2 levels, increased oxygen capacity, the absence of any variations in the blood amino-acid and phosphorus levels and a considerable increase in the chlorine level.

Analysis of the dog urine showed a considerable increase in the inorganic alkalis and chlorine, an increase in total acidity but no variation in the ammonia level and no increase in the total amount of nitrogen and organic acids. These data again indicate absence of acidosis.

To the main question, whether acidosis or alkalosis set in at altitude, the investigators replied as follows: "the fall in the fanial pressure of oxygen in the alveolar air is primary and this probably leads to a temporary short tissue acidosis, to which the nervous system, particularly the respiratory center, reacts vigorously. This in turn leads to intensified pulmonary ventilation, resulting in alkalosis, which cancels out the initial acidosis; the two opposite processes constantly alternate".

Lastly, investigations of the blood morphology revealed a rise in the erythrocyte count and hemoglobin level, both of which remained high throughout the period at high altitude. The erythrocyte count continued high for one to two months after the return to Leningrad. As regards the leucocytes, apart from a slight shift towards lymphocytosis, no variation could be detected.

The results obtained from the biochemical investigations in these two expeditions and the conclusions based on them were new in Soviet physiology. The physiological investigations largely confirmed existing data (Tret'yakov, 1897; Lavrinovich, 1899, Gorbachev, 1892, Glinchikov, 1905 and others). The problem of the organism's functional adaptation to so unusual a factor as reduced atmospheric pressure had received little attention from Soviet physiologists before this expedition and the question of the organism's adaptation to low partial pressure of atmospheric oxygen had never even been raised; so it was natural that the Bykov-Martinson findings should stimulate further expeditions to continue the work they had started.

From the point of view of aviation physiology the expeditions yielded a great deal, particularly the discovery that the acid-alkali balance remained constant at low altitudes and that polyglobulia persisted after a period at altitude.

The first of these conclusions was important because the existing literature was completely contradictory in regard to the acidosis-alkalosis question: most European investigators believed that acidosis inevitably developed at altitude, whereas the prevailing American view was that alkalosis developed. The Bykov-Martinson investigations showed, for the first time, that owing to the presence of a number of physiological regulatory mechanisms, capable of very rapidly compensating disorders in the acid-alkali balance, no drastic modification of the active blood reaction at altitude need occur.

The second conclusion indicated that the organism had the capacity to retain a "heightened level of the processes" for a long time, resulting in the "rejuvenating effect of a high-mountain climate". This was of immense importance for aviation medicine too: the discovery, stressed by Bykov and Martinson, that high erythrocyte and hemoglobin indices were retained in the blood for one to two months after a comparatively short stay at moderate altitude, provided physiological justification for the pressure-chamber method of training fliers, which at that time had only just come into existence.

5

Sirotinin's expeditions made him one of the greatest Soviet experts on mountain sickness and were of immense importance in revealing the effect of reduced atmospheric pressure on the human organism. His aim was to investigate the etiology, pathogenesis and clinical picture of mountain sickness and to work out a prophylaxis.

To this end he organized nine scientific mountaineering expeditions, apart from his own personal ascents, the first of which he made in 1926 when he climbed the Georgievsk glacier on Mount Kazbek. Apart from Sirotinin himself the expeditions considted of Ado, Aksyantsev, Vylegzhanin, Erzin, Kalinovskii, Kalinovskaya, Malkina, Pashaev, Popov, Samtsov, Timofeeva, Fazlulin and a number of other people.

In nearly all these expeditions the key question for Sirotinin was the condition of the acid-alkali balance at altitude. His preoccupation with this question was due to his idea that disorders of the blood acid-alkali balance lay at the root path of altitude and of mountain sickness. An active alkaline reaction of the blood would be an indirect factor in the development of mountain sickness. This idea permeates all his work and more recently he has formulated it as follows: "in non-gaseous acidosis only the very slightest symptoms of mountain sickness can be detected; the main signs of the disease are connected with the gaseous form of alkalosis" (Sirotinin, 1950).

Much of the work done during the ascents was aimed at demonstrating this proposition. A considerable reduction of the reserve alkalinity in the blood

and a slight shift of the blood reaction in the alkali direction, coinciding with the onset of symptoms of mountain sickness, had been noted at an altitude of 4200 m, back in 1930. In 1932 normal blood reaction was observed at this altitude, but at 5015 m the active reaction of the blood altered violently in the alkaline direction, with simultaneous onset of the symptoms of mountain sickness. In 1933 alkalosis was again recorded at 4250 m, again accompanying symptoms of mountain sickness. In 1935 a similar change in the blood pH was observed at 5000 m and it was established that the more abrupt the shift in the direction of alkalosis the more severe were the symptoms of mountain sickness.

As a result of all these investigations it was shown that at moderate altitudes a tendency to acidosis could be detected, accompanied either by none of the symptoms of mountain sickness or by very mild symptoms. At higher altitudes the acidosis was overlaid by gaseous alkalosis, accompanied, as a rule, by severe manifestations of mountain sickness.

It is difficult to tell at present how far the attempt to connect the pathogenesis of mountain sickness solely with changes in the active blood reaction was justifiable. This was one of the theories of mountain sickness pathogenesis of the 1930s. Subsequent research will either corroborate or disprove it, but in the 1930s and 1940s Sirotinin was its brilliant champion.

A second question claiming Sirotinin's attention was the problem of changes in the blood morphology during a period at altitude. Data indicating an increase in the erythocyte and hemoglobin count under conditions of reduced atmospheric pressure had been obtained as long ago as 1930. It was subsequently noted that under mountain conditions new red blood cells, or reticulocytes, formed and Vylegzhanin (1939) succeeded in establishing the existence of a reticulocyte regeneration shift, indicating intensified hematopoiesis. Sirotinin was inclined at first (1934) to regard altitude reticulocytosis as the result of ultraviolet radiation, but later (1950) he attributed the increase to reduced atmospheric pressure.

These changes in the morphological picture of the red blood impelled Sirotinin to tackle the problem of altitude acclimatization seriously. Some work on this problem was done in nearly all the expeditions, but the most important in this respect was the 1938 expeditions, when a seven-day stay on Kazbek (at 4000 m) raised the pressure chamber "altitude threshold" of all the participants in the expedition "by more than 1000 m"; this heightened tolerance and modification of the red blood in the polyglobulia direction was retained in the organism for one to one and a half months after the descent. From this it was concluded that one of the basic mechanisms of altitude acclimatization was increase in the oxidizing surface of the blood, due to polyglobulia.

The presence of reticulocytes at altitude indicating intensification of the erythropoietic function of the bone marrow, stimulated Sirotinin to try and discover the mechanism of this phenomenon. Bogomolets, as we know, adhered to the view that in these cases the stimulus to the bone marrow was not lack of

oxygen but the decay products of the erythrocytes and that erythrodieresis preceded and conditioned the erythropoiesis. Sirotinin tried to demonstrate this during his expeditions. For some reason it was impossible to use the results of blood bilirubin investigations for this purpose, but determination of the globulin in the urine gave very indeterminate results even at 5633 m. In short, it proved impossible to demonstrate experimentally that erythrocyte decay was intensified at altitude. Nevertheless, in a chapter on The effect of respiration at reduced atmospheric pressure in the Manual of pathological physiology (1936) Sirotinin asserted definitely that intensified erythrocyte decay occurred at altitude, accompanied by the appearance of hemoglobin in the urine and even by hematuria.

Along with these key questions Sirotinin's expeditions solved a number of other problems. It was established, for example, that the blood glutathione increased at altitude and that excretion by the skin did not intensify, as had been supposed. Investigations of the cardiovascular system showed that the pulse rate increased during the ascent but reverted to normal during 4 to 5 days' stay at 4260 m. No characteristic variations whatsoever could be detected in the blood pressure. Investigations of the heart boundaries in 22 workers who lived for a month and a half at 4190 m revealed an increase in the left boundary of the cardiac dullness. Investigation of the higher nervous activity by psychotechnical tests showed that at 2000 m the excitation process predominated, expressed as a heightening of mood and sharpening of the memory and other "mental faculties". But at 4000-5000 m psychic depression was observed, expressed as deterioration in the attention, memory and judgement and loss of precision of movements. At the same time, faculties such as the ability to do rapid calculations, local memory and resistance to fatigue improved. No change was observed in rapidity of movement, the ability of the eye to measure or the organization of attention. Investigation of muscular power showed that although muscular capacity to work was reduced at altitude, this could not be established with a squeeze dynamometer, but that the strength of the backbone was slightly reduced. Lastly, it was established that sexual potency was reduced at altitude.

Sirotinin paid great attention in his expeditions to prophylaxis against mountain sickness. Assuming that the chief factor in the pathogenesis of mountain sickness was alkalosis he suggested taking citric acid. Tests with citric acid in sugar syrup and with soda showed that those subjects who had taken the citric acid contracted mountain sickness much later than those that had taken the soda. From this it was inferred that the introduction of acid substances to suppress the alkalosis must militate against the development of mountain sickness.

This brief account of the results of Sirotinin's nine mountaineering expeditions cannot, of course, cover the whole range and variety of his investigations. All the work done by him and his co-workers was a valuable contribution to the physiological response to high-mountain climates and aviation medicine made wide use of the scientific results of these expeditions.

6

The most comprehensive work on the problem of altitude physiology was performed in the seven joint expeditions organized by the USSR Academy of Sciences and the All-Union Institute of Experimental Medicine, in which the Kirov Academy of Military Medicine and the third Leningrad Medical Institute took part. All the expeditions were essentially a continuation of the work started by Bykov, who was their guiding spirit.

The expeditions can be divided into two groups of five (1934-1938) and two (1939 and 1940) respectively. The distinction is essential because the general direction of the work was different in the two groups. While the main trend in all seven expeditions was biochemical and the basic work was done by the Department of General Physiology of the All-Union Institute of Experimental Medicine and directed by Academician Bykov, the physiological work done by the Department of Physiology and Pathology of the Sense Organs under Grashchenkov took up a good deal of time in the first five expeditions. Moreover, in the 1938 and 1939 expeditions members of Razenkov's nutrition laboratory (of the All-Union Institue of Experimental Medicine) took part. Vladimirov and Zhukov respectively were the immediate directors of the biochemical and physiological work.

The biochemical team consisted of Baichenko, Goryukhin, Dedyulin, Dmitriev, Efremov, Kovalenko, Kryukov, Kuntsevich, Lorberg, Milyushkevich, Oppel', Ostrogorskaya, Panin, Raiko, Rikkel', Stremilova, Epshteyn.

The physiological team consisted of Aronova, Boldyrev, Vereshchagin, Grigor'ev, Gromov, Minut-Sirokhtina, Piontkovskii, Peshkovskii, Rappoport, Raeva, Musaelyan, Stepanov, Timofeev, Fedorova, Fedorov, Frank, Shteingauz, Kharitonov, Khachaturyan, Uspenskii, Khazen, Shlygin and others.

As most of the physiological team took part in the first five expeditions I shall deal with its work first. This was aimed mainly at investigating the functions of the central nervous system, the vegetative nervous system and the analysors under conditions of reduced atmospheric pressure. Zhukov, realizing that the effect of reduced atmospheric pressure on the respiration, blood, circulation and metabolism had been the subject of many investigations but that only a few scattered observations existed in regard to the nervous system and the analysors (1943) and already interested (1936a and b) in the functional variations in the analysors, directed the main effort of his team to this question.

The sensitivity of the skin was investigated by chronaximetry. Although considerable discrepancies were found in the numerical indices, the general dynamics curve remained roughly the same. Variations in the skin sensitivity were observed even at 2200 m. They took the form of changes in the tactile sensitivity, no change at all being observable in the sensitivity to pain. At 4250 m the chronaxy of the tactile sense was longer, indicating "reduced lability due

to changes in the organism caused by altitude factors" (Zhukov, 1936b). At the same time it was found that the thresholds of the corneal and conjunctival sensitivity were slightly lowered at altitude. Tests with Frey's hairs produced unexpected results, revealing enhanced sensitivity to slight threshold stimulations but reduced sensitivity to strong stimulation. The investigations yielded no more detailed information on this paradoxical effect.

Even at 2200 m the acoustic-sensitivity threshold rose and there was a particularly sharp deterioration in the preception of frequencies of 6000-10,000 c/s; at 4250 m the deterioration in acoustic sensitivity was very marked. The musical hearing deteriorated particularly sharply at altitude. People who normally had no difficulty in tuning musical instruments found that their capacity to differentiate tones sharply deteriorated at altitude. The duration of the stay at altitude characteristically involved no deterioration of the hearing.

Chronaximetric investigation of the vestibular apparatus at 2200 m revealed a sharp increase in excitability, particularly in people less tolerant to altitude; this was observed, however, only on the first day at altitude and the vestibular excitability subsequently reverted to normal. The excitability of the vestibular apparatus was not determined at high altitudes.

Chronaximetric investigation of the visual analysor revealed progressive heightening of the excitability of the visual apparatus with height. At 4250 m the sensitivity to yellow, green and blue was perceptibly lower but the sensitivity to red was unaltered. The field of vision narrowed even at 2200 m (for blue). At 4250 m it was 70 per cent narrower for blue but had not changed for red and green. A "perverted reaction" of the blind spot was noted at altitudes. Some changes occurred also in the diameter of the pupil, which perceptibly increased while at the same time the reaction to light diminished.

Investigation of the olfactory sense showed that the thresholds for perception of substances eliciting the sensation of odor and the thresholds for clear recognition of odor rose considerably. At 4250 m, for example, these thresholds were twice their former value.

Investigation of the sense of tests revealed dissimiliar variations in the perception thresholds at altitude. Acid, salt and bitter tastes were at first more acute in proportion to the altitude, but after a few days at altitude they reverted to the initial level. The sweet taste became progressively blunter with altitude.

In studying the variations in the different kinds of sensitivity at height the investigators adopted Head's conception in its entirety and the general conclusion to which Zhukov came was that under conditions of reduced atmospheric pressure the epicritical forms of sensitivity in the main were disturbed but the protopathic sensitivity remained more stable.

The conclusions reached by Grashchenkov's coworkers as a result of their observations under high-mountain conditions thus fully coincided with those of Strel'tsov (1938b), obtained as a result of pressure-chamber observations. It must be admitted that more detailed analysis of the findings of both groups by no means always corroborated the view that the first sensibilities to suffer under anoxic conditions were those which Head classified as epicritic; but the fact that the views of two separate groups of investigators coincided indicates that in the 1930s Head's conception had received wide recognition among a number of Soviet physiologists. Only later did facts accumulate which did not fit into this theory, based on the arbitrary and improbable assumption of a phylogenetic sequence in the development of the various kinds of sensibility.

Other physiological functions were investigated at the same time.

Salivation. The peculiarity of this function at altitude lay in the fact that, whereas the salivation intensified in response to increasing concentrations of stimulus on low ground, at altitude any concentrations elicited roughly identical responses.

As has been shown above, Razenkov's coworkers obtained different results.

Respiration. That respiration intensified at altitude and that this compensatory mechanism was highly labile and set in rapidly had long been known in physiology. It was now shown that intensified respiration did not seem to start immediately but only the expeditions' findings on the variations in the character of the breathing tallied exactly with accepted views. Hyperventilation usually sets in at altitude, the respiration becoming quicker and slightly deeper. But the investigations showed that in some subjects the breathing intensified owing to the increased frequency of respiration while in others it was due to the deepening of respiration. At rest, the intensification seemed to be negligible, even at 5633 m, but very slight movements, particularly in connection with work, caused the respiration to become not only much more intensive but also spasmodic, intermittent and quite insufficient. The time during which the breath could be voluntarily held was reduced. The investigators believed that the altered character of the breathing was proof of heightened excitability of the respiratory center and assumed that at altitudes above 5000 m this would fall into a state of paresis.

Blood circulation. Reactions of the cardiovascular system included quickening of the pulse, slow return of the frequency of the cardiac contractions to normal after rationed work, negligibly small rise in the systolic blood pressure, slight variations in the diastolic pressure and higher venous pressure. In the orthostatic test at 4250 m and particularly at 5315 m the blood pressure usually fell. The duration of blood flow on puncturing to a controlled depth greatly increased (up to "many tens of minutes" at 4250 m, against 3-5 minutes in Moscow). The coagulation rate fell at altitude. The investigators were unable to detect any variations in the electrocardiogram at 2200 m but at 4250 m

they observed increased R and P waves and a splitting of the P wave; T thickened at this altitude only after work.

The red and white dermographia thresholds rose at altitude. At 4250 m the skin galvanic reflex "lost its biphasal or multiphasal character and took the form of a single, slow, long drawn out and, so to say, stiff reaction". The cavity and skin temperature, in the comparatively resting condition, showed no appreciable deviation from the values obtained on low ground.

At 4250 m the muscular chronaxy increased by roughly 80 per cent but the neural chronaxy was 20 per cent shorter. The muscle and joint sense was considerably disturbed at this altitude. Tremor progressively increased with altitude both at rest and in movement. Work efficiency was lower at altitude than in the plain, the ergogram recording values 33 per cent lower at 2200 m and 57 per cent lower at 4250 m. This reduced efficiency was expressed as a reduction in the number of loads lifted, but the absolute height of the concentrations did not appreciably alter. At 4250 m the work time was reduced by a factor of 3.

Along with the investigations on variations in the vegetative functions the effect of certain pharmacological substances at altitude was studied. Attention was concentrated particularly on caffeine, luminol and a combination of the two. The investigators formed the impression that although caffeine had a beneficial effect on the work of the heart at altitude, on the whole its effect was rather adverse. Much better results were obtained from luminol or a combination of luminol and caffeine.

Zhukov's conclusions about the effect of breathing oxygen at altitude are rather odd: in his own words, inspiration of oxygen was beneficial only during the first days at altitude, "but later it gave no benefit and even had certain unpleasant effects" (Zhukov et al., 1939).

All these findings required some sort of general, theoretical interpretation. Zhukov provided this by putting forward, for the first time, the notion of "the paramount importance of the central nervous system in all these disorders". In his opinion, theffunctional changes detected in the cardiovascular, respiratory, neuromuscular and other systems could not be due to the effect of anoxia on the organs themselves; the reactions of these systems must be due to the effect of anoxia on the central nervous system.

These propositions were undoubtedly true, but subsequent discussion made Zhukov dissatisfied with his picture. He believed that the whole complex of altitude factors had a stimulating effect not so much on the cerebral cortex as on the regions "situated below the cerebral cortex", primarily the higher vegetative centers. Here he assumed that the complex of altitude factors directly stimulated the higher vegetative centers and that as a result of this stimulation the vital activity of a series of centers altered, bringing about reflex changes in the sensibility and variations in a number of vegetative functions. Among these changes, biochemical variations had very great importance; these acted in turn on the C.N.S., with the result that" . . . a sort of spiral is

produced, not all the systems being able to maintain the level of vital activity essential to the organism".

Such was the basic conception or working hypothesis regarding the physiological effect of altitude built up by Zhukov and Grashchenkov. Nowadays it can no longer be considered satisfactory, although Zhukov did develop it further in his doctorate thesis on the Role of the nervous system in changes in the working capacity and reactivity of the organism in mountains (1943). This new theory of the pathogenesis of mountain sickness was unsatisfactory in that it was too remote from the only correct, Pavlovian idea of the mechanism by which various kinds of stimulating factors operate.

Nor was Vvedenskii's parabiosis theory accepted. It is curious to note that one of Zhukov's coworkers (Timofeev, 1935), investigating variations in the salivation function at altitude, reached the conclusion that under these conditions a "parabiotization of the cells in the lower sections of the brain" occurs; but this idea, expressed for the first time in the history of high-mountain physiology, does not seem to have been received sympathetically and was not further developed.

7

The work of Vladimirov's biochemical team, based on a broad, well thought out plan of research, consisted in a series of thorough and careful experiments of remarkable scope, variety and complexity. Vladimirov and his numerous coworkers aimed at studying the processes regulating the respiratory function of the blood and the metabolism under conditions of reduced atmospheric pressure—the problems which had first been tackled by Bykov's expeditions and which now needed further investigation and refinement. The ultimate purpose was to find out the nature of the physiological process of altitude acclimatization and to work out methods of combating or at least mitigating altitude sickness and of improving working efficiency at altitude (Vladimirov, 1938; Vladimirov, Dedyulin et al., 1939a and b, etc.).

During his first expeditions Vladimirov had supported the view that the basic factor in altitude acclimatization was hemoglobin and he was therefore specially concerned to discover the dynamics of the variations in the hemoglobin level at altitude.

The very first expeditions showed that a long stay (one month) at 3000 to 4250 m caused the oxygen capacity of the blood to increase, on the average, by 20%. At the same time Vladimirov became convinced that the process of adaptation to altitude did not correspond to the process of new erythrocyte formation. The latter occurred slowly and required many days for its completion, whereas the process of adaptation to altitude was fairly pronounced after two or three

days at altitude. This implied that other factors were important in the acclimatization process, in addition to the rise in the hemoglobin level. Those factors would be particularly important in cases where rapid adaptation was necessary.

This made it essential both to study in detail the physical and chemical variations in the blood and to concentrate on finding out how the conditions of oxygen supply to the tissues were regulated.

The data obtained showed primarily that the blood viscosity increased at altitude. Blood which gave a reading of 4.9 on the Determan viscosimeter on low ground gave a reading of 7.1 at 5300 m.

The difference between the arterial and venous oxygen level was distinctly reduced at altitude, indicating that the oxygen level in the venous and consequently in the capillary blood at altitude was high. The reason for the reduced difference was not that the tissues absorbed less oxygen at altitude but rather that the amount of blood reaching the tissues increased. In other words, the minute volume of the heart increased. It was found that a minute volume of 3-4 liters on low ground rose to 7 liters at 4250 m and to 9 liters at 5315 m. The inference was that an increase in the minute volume of the heart must be regarded as one of the mechanisms of acclimatization to altitude.

Much research was devoted to the chemical properties of the blood, particularly the gas-electrolyte and acid-alkali balance. It was found that the partial pressure of CO_2 in the alveolar air was reduced with altitude, along with the total CO_2 content and the CO_2 capacity of the blood; the active reaction of the blood shifted in the direction of alkalinity.

To find out why the CO_2 capacity of the blood was reduced at altitude it was necessary to investigate the lactic acid content of the blood and the electrolytes of the blood plasma. It was found that the total electrolyte count did not alter with altitude but at very high altitudes (5300 m), some variation in the cation composition was observed, amounting to an increase in the potassium level and a decrease in the sodium level. At the same time it was established that a reduction in the amount of bicarbonates and consequently a reduction in the CO_2 capacity was due to an almost equivalent increase in the sum total or organic acids. It was found that the lactic acid level in the blood rose.

Comparison of the organic acid level, determined in toto by electrometric titration, with the lactic acid level showed that a considerable part of the increase in organic acids must be attributed to the so-called X acids. Since the increase in these reflected some kind of metabolic alteration at altitude, Vladimirov decided to study this too.

The increase in the lactic acid content and total amount of organic acids in the blood and, in particular, the increased amount of acetone bodies in the urine indicated disorders of the intermediate metabolism at altitude. The accumulation of ketone bodies and the considerable increase in the β-hydroxybutyric acid level in the liver indicated functional disturbances of the hepatic function at altitude.

The changes detected in the blood and urine chemistry indicated that at high altitude the fat metabolism of the organism was the first to suffer and that it was therefore necessary to reduce the amount of fats in the food ration and substitute more readily utilizable carbohydrates, in particular sugar.

Investigation of the carbohydrate metabolism showed that the capacity of the tissues to oxidize carbohydrate suffered no appreciable disturbance at altitude. Moreover, the capacity of carbohydrates for isodynamic substitution in the fat metabolism was fully retained at altitude. So too was the antiketonic action of carbohydrates. The specifically dynamic action of sugar administered at altitude was reduced but its oxidation was slightly accelerated. Administration of sugar at altitudes higher than 3000 m greatly reduced ketonuria. These changes in the carbohydrate metabolism led Vladimirov to the practical conclusion that a mountaineering food ration containing a preponderance of more readily assimilable carbohydrates must be devised.

In regard to the protein metabolism and its variations at altitude, it was established that the deamination of the products of protein hydrolysis was slightly disturbed at altitude and that the specifically dynamic action of protein was reduced, but the excretion of the end products of the protein metabolism proceeded as rapidly as under lowland conditions. These data led to the conclusion that the accepted standards for protein rations for use in low terrain would be satisfactory also at altitude.

The problem of variations in the basal metabolism at altitude, still the subject of controversy in the literature, was extremely topical at the time we are discussing. Vladimirov's investigations showed that the basal metabolism rose. According to his data the mean values for basal metabolism in 8 subjects were 1720 cal. under lowland conditions, 1765 cal. at 3000 m and 1782 cal. at 4250 m. But at the same time Vladimirov found that in two of his eight subjects the basal metabolism actually diminished at altitude, although it rose in the other six.

A prolonged stay at altitude produced distinct acclimatization change in a number of physiological functions: gradual reduction of the minute volume of the heart, increase in the erythrocyte count due to the formation of new erythrocytes, reduction of the amount of acetone bodies excreted with the urine, and a number of other indices. In regard to hemoglobin, Vladimirov thought that variations in the hemoglobin level could not be regarded as a basis factor in acclimatization and that the acclimatization process consisted in the integration of a series of physiological functions.

After so much mountain research Vladimirov could not but wonder whether high-mountain ascents might not be an effective way of improving anoxia tolerance. He therefore determined the individual anoxia tolerance of 24 subjects before a high-mountain ascent and after a 40-days' stay at altitudes above 3000 m. He found that after this period in the mountains the individual "altitude ceiling" rose and that the improved tolerance persisted for not less than two months, in some cases up to one year. Loss of consciousness before the mountain ascent occurred, on the average, at 7966 m; after a month in the mountains loss of consciousness set in on the average at 8883 m and after two to three months at 8923 m. The improved tolerance was the result of the general training of the organism and the training of the cardiovascular system and the vegetative nervous system.

It was noted, however, that a stay in the mountains, although improving individual tolerance to critical degrees of reduced pressure, had hardly any effect on the capacity to withstand rare atmosphere for many hours.

A striking discovery in these investigations was that a period in the mountains made hardly any difference to the tolerance in sportsmen but greatly improved it in people who did not engage in any sport.

It was established also that the initial hemoglobin level in the blood was not of prime importance in relation to altitude tolerance.

Lastly, it was shown that inspiration of oxygen at altitude indiced a rapid fall in the hemoglibin level and a rise in the blood-sugar level but that the acid-alkali balance was restored very slowly. Vladimirov was inclined to regard this slow restoration of the acid-alkali balance as the reason for the slight effect of oxygen inspiration in the mountains as compared with the pressure chamber.

So cursory a review cannot, of course, give a complete picture of the manifold contributions these mountaineering expeditions by physiologists made to science. I have deliberately omitted much detail and many minor discoveries and I have not even mentioned several Soviet expeditions. This implies no undervaluation of their work; but they are irrelevant to my purpose here, which is to show the contribution of each work to aviation medicine.

This related to one problem alone: the effect of reduced atmospheric pressure on the human organism. Herein lies the basis of all aviation medicine; any new data, throwing fresh light on even a part of this immense problem, are of obligatory interest to aviation medicine. A man flying an aeroplane is operating under very different conditions from a man climbing a high

mountain; nevertheless, the pattern followed by the majority of the physiological functions is the same in both cases and the general, fundamental propositions formulated as a result of practical experience by the Soviet mountaineering expeditions are equally valid for aviation medicine. The immense amount of work done by the physiologists under exceptionally severe meteorological conditions in high mountains therefore represents a priceless contribution not only to mountaineering physiology but also to aviation medicine

The high-mountain expeditions established a vast number of new facts in regard to the peculiar course of a number of physiological processes when man finds himself under conditions of reduced atmospheric pressure. These processes, the variations in the nervous regulation of the activity of organs and tissues, could now be seen to follow definite patterns. The human organism was seen to possess immense regulatory and compensatory possibilities. The physiological mechanism of such complex processes as acclimatization and adaptation to reduced atmospheric pressure was discovered.

Intricate and confusing questions such as the condition of the acid-alkali balance and of the electrolytic balance at altitude, variations in the gas composition of the blood were clarified. Much new information was obtained about the respiratory function of the blood, the process of oxyhemoglobin dissociation, the oxygen and carbon dioxide pressures in the blood, the oxygen and carbon dioxide capacity of the blood and so forth.

The behavior of a number of vegetative functions under conditions of reduced atmospheric pressure became clearer. Variations in the blood circulation, respiration, digestion and thermal regulation were more precisely defined and a clear pattern emerged.

With the new, more precise data on metabolic processes at altitude it became easier to design a proper diet for use not only in mountain ascents but also in high-altitude flights.

By treating the processes of acclimatization and adaptation to altitude as the integration of a series of physiological functions, the expeditions provided physiological justification for training aviators in pressure chambers and refined the concept of altitude tolerance.

Lastly, the mountaineering expeditions produced much material showing the leading role of the central nervous system and, particularly, of the cerebral cortex in the organism's reactions to reduced atmospheric pressure.

All this meant that Soviet physiologists now had a comprehensive and detailed picture of the problem of anoxia, which now became clear and accessible both to the clinical practitioner and to the flight doctor.

ESSAY IX

AVIATION MEDICINE IN THE USSR DURING THE SECOND WORLD WAR

Before the war the medical service of the Soviet Air Force consisted of a large number of unit medical officers and of the specialized surgeries attached to the flying schools. The laboratories of aviation medicine, which had flourished in most commands for a few years before the war, were abolished shortly before war broke out (they were retained only in the Navy). All medical services in Air Force units in the various commands came under the Air Officer Assistant Chief of the Distinct Army Medical Administration. At the center were the Scientific Research Experimental Institute of Aviation Medicine and the clinical department of this Institute, based on a number of departments of the First Moscow Communist Hospital. The entire medical service of the Air Force came under the Seventh Division of the Medical Administration, headed by the Air Officer Assistant Chief of the Medical Directorate.

With the outbreak of war the Air Force medical services faced much more complicated problems and radical reorganization was needed. Much laborious groping was entailed in finding the most acceptable forms of organization and the reorganization period lasted almost until the end of 1944.

This was due to the role which the Air Force began to play in the war. As we know, the war can be divided into four periods: 1) June 1941 to November 1942, 2) November 1942 to December 1943, 3) 1944 and 4) 1945. The first period was one of maneuver warfare and the Air Force was somewhat divorced from the ground forces. The second period was partly a prolongation of the first, but it also saw the great battles of Moscow, Stalingrad and Kursk, in which Air Force units played an active part. The third period covered the ten strategic attacks of the Soviet armies; Air Force units were already performing highly complicated, responsible and independent tasks. This was a period of considerable growth for Soviet air power. There was an immense increase in the numerical strength of the Air Force, units were frequently transferred to new bases, losses were high. The fourth period, when the Soviet Army achieved victory over the German Fascists, was the time when the air forces carried out their most complicated tasks.

The reorganization of the Air Force Medical Service started in September 1941, when Section VII of the Health Directorate, under the Air Force

Health Service, was abolished. It was not replaced by any other organization and until May 1942 there was no central authority responsible for the Air Force medical services. In March 1942 the medical service of the Strategic Air Force was reorganized and became an independent "Strategic Air Force Medical Division" under I.M. Pruntov. In April 1942 a medical officer of flag rank was appointed to the Air Force General Staff and a number of inspectors were allocated to him. The first officer to hold this post was L.G. Ratgauz. The reorganization of the Air Force medical services was part of a general reorganization of the Air Force. In mid-1942 three special corps — pursuit, low-flying attack and bomber — were formed. In November 1942 separate air commands were established. This form of organization involved appointing corps doctors and medical officers of flag rank to the Air Commands.

It became essential to organize properly the evacuation of aircrew casualties. Air Force sections had been formed in one of the front-casualty hospitals as early as 1942 and in 1943 each Air Command had its own hospitals. These catered for all Air Force personnel and had their own surgical, ophthalmological, otolaryngological, therapy, neurological and skin and venereal disease divisions. With the organization of the command hospitals and the simultaneous conversion of the clinical division of the Institute of Aviation Medicine into a central Air Force hospital it became possible to put the evacuation of sick and wounded fliers on an efficient basis. The men were evacuated from the base clearing station to the command hospital and then transferred, depending on the indications, to the central Air Force hospital or to the specialized front hospitals.

The final stage in building up a well-ordered system of therapy and prophylaxis for Air Force personnel was the introduction of Air Force rest homes at the end of 1942 and of mobile sanitation and epidemiological laboratories in certain air commands in 1944.

A corresponding reorganization took place in the central administration of the Air Force medical services. The medical Air Officer and his division were replaced in 1944 by an Air Force Medical Administration. Ratgauz was made head of this, with A.P. Popov as his deputy. At the end of 1944 the appointments of chief surgeon and chief therapist to the Air Force, under the Administration, were introduced.

I have already mentioned that the Institute of Aviation Medicine was abolished in April 1943. In its stead the Laboratory of Aviation Medicine attached to the Department of Physiology of the Kirov Military Medical Academy, with Brestkin as its chief and under the direction of Academician Orbeli, was expanded.

The entire reorganization of the Air Force medical services was due, on the one hand, to the gradual growth of the Air Force and the new tasks facing the Air Force medical service in wartime and, on the other hand, to the necessity of building up a corps of flight doctors capable of performing these tasks. The question of medical recruitment was particularly acute in the first period of the war. This was because many qualified flight doctors were promoted

to ground units and largely replaced by doctors from the reserve who had graduated from civil medical schools and had no training whatsoever in aviation medicine. This made it urgent to put the training of flight doctors on a proper basis.

The problem was not solved until the second period of the war, when courses for further medical training were started at the Central Institute's Department of Aviation Medicine and flight doctors were posted to these for periods ranging from two to six months. Some contribution to the training of flight doctors was made by the training camps which were systematically held in the individual air commands. The clinical training of flight doctors was achieved by seconding them to various hospitals. In the third and fourth periods of the war these training arrangements had already become systematized.

The inadequacy of central direction during the first period of the war, the special character of the Air Force units' work in this period and the new tasks in regard to the treatment and prophylaxis of Air Force personnel all meant that the Air Force medical service was confronted with completely new problems. In the main, these amounted to the proper organization of treatment, the organization of search operations for fliers brought down in battle, their evacuation to specialized hospitals and the proper organization of epidemic control and sanitation and hygiene work. There were also the acute problems of diet, overstrain and battle traumatism. These problems necessitated devising special emergency rations for accidents or forced landings in isolated places. Such an emergency ration was in fact designed and became standard equipment in the very first months of the war. It consisted of three tins of condensed milk, three tins of potted meat, 800 g of biscuit, 300 g of chocolate and 400 g of sugar (total calories 12190, amply sufficient to sustain a man for three days or if necessary even longer).

Attention was paid also to the improvement of aircrew maintenance, to regulating the number of missions required from them and to making provision for timely rest periods. As early as 1942 the Air Force Command issued a series of instructions on the mission load and the automatic right of aircrew personnel to rest after a definite number of sorties. The pressure-chamber training for high altitudes, which had been widely practiced before the war, was now stopped, because the great majority of flights were at low altitudes.

The medical work started in the first period of the war was carried further in the second period. Attention was devoted mainly to countering fatigue and overstrain. On the initiative of individual senior flight surgeons aircrew rest homes were organized, first in some and finally in all (1943) the air commands. The work of unit sickbays was improved and finally put on a proper footing. Air-search arrangements, in which all unit flight doctors took part, were put on a proper footing.

Careful study of battle traumatism in Air Force units led to intensified training of fliers in the rules of self-help and mutual aid and to improvement of the first-aid equipment carried on board aircraft. Two types of first-aid sets were devised, No. 1 (large) and No. 2 (small). The basic equipment

consisted of bandaging material, iodine, anti-burn ointment and several other medicaments.

At the same time a great deal of thought was put into devising and rationalizing various kinds of protective equipment for the flier. A place reserved for the seriously wounded was introduced into aircraft, metal helmets and breastplates were designed. Special fluids for drenching the clothing in the event of fire were devised, and so forth. Flight doctors played an active part in this work.

All this work was carried further during the third and fourth periods of the war and the creation of Air Force hospitals completed the organization of the Air Force medical service.

Aerial evacuation contributed immensely to helping the sick and wounded during the war. Before the war there had been only three hundred and fifty machines available for this purpose, mainly S-1 and S-2 but during the war the S-3, Li-2, Shche-2 and Po-2Shs appeared. By the second period of the war there were 430 and by the third period 691 aircraft available for evacuation pruposes. Apart from these specially equipped planes, all transport aircraft carrying freight or reinforcements to the front were used for evacuating the sick and wounded.

Many thousands were thus brought back to base hospitals. Unfortunately, there seem to be no exact statistics on this work and the figures reported by individual investigators do not always agree. Kaktysh (1942), for example, mentions "many thousands of sick and wounded evacuated during the first 10 months of the war alone"; Romanovich says that during the first period of the war alone tens of thousands were evacuated by air and an immense amount of blood and 324, 612 kg of medical supplies delivered to the front.

During the war certain changes were made also in regard to Air Force medical boards. These had the extremely responsible job of deciding on the fitness of men who had been wounded. The decision often had to be made when such important documents as the flier's medical record, maintenance record and service record were not available.

Before the war the basic documents governing the work both of Air Force medical boards and of group flight surgeons were the relevant instructions of the Peoples' Commissariat of Defense, the Manual for Air Force Medical Boards (1941), the Instructions on Aircrew Examination (1941) and the Instructions on the physical condition and state of health of aircrew personnel (1941).

During the first period of the war the regular annual reexamination was stopped, systematic aircrew maintenance was upset and because of the inadequate training of doctors drawn from the reserve, there was no careful inspection of fliers' medical records. The very first months of the war, however, showed that it was essential to amend the Defense Commissariat's

instructions accordingly and as early as 1941 the main military medical directorate issued a new instruction laying down health standards for aircrew, which remained in force throughout the war.

In the second period of the war all these shortcomings were largely corrected. Aircrew personnel were again required to carry their health records, flight doctors were given instructions on the necessity of systematic aircrew maintenance and obliged to keep special daily records of the state of health of flying personnel; they were instructed also about the necessity of identifying and "tagging" fliers suffering from various physical defects. Admittedly, no unified procedure for medical observation of aircrew was devised and each flight doctor went his own way in this matter. In the second period of the war, however, another very important step was taken with the introduction of compulsory annual medical boards for flying personnel.

In the third period of the war all this work was systematized and brought to a fairly high level. The procedure for medical observation of aircrew personnel was considerably improved; so too was the work of the medical boards, mainly by taking them out of the hands of hospital specialists who rarely knew enough about the special conditions involved in flying and handing them over to experts from the air hospitals.

The prewar research on problems of interest to aviation medicine was greatly curtailed and in some cases shelved for the duration. Many research institutes had to be evacuated into the depths of the country, where experimental work was difficult. Many learned periodicals ceased publication. In the first half of 1941, 112 scientific papers directly bearing on aviation medicine were published in various journals; during the second half of the year only 16 appeared. In the next two years scientific research continued to stagnate. Only 33 papers were published in 1942 and only 10 in 1943. There was some revival in 1944, when the number of papers published rose to 46 (38 in 1945).

The scientific research institutes which continued working on problems of aviation medicine during the war were the Institute of Aviation Medicine, the Kirov Academy of Military Medicine, the Naval Medical Academy, the Air Force Central Medical Examination Laboratory and the Department of Aviation Medicine at the Central Institute for Further Medical Training. To some extent work continued also in some departments and laboratories of the All-Union Institute of Experimental Medicine and in the Physiological Institute of the Academy of Sciences. Rank-and-file flight doctors made a considerable practical contribution to scientific work.

The Institute of Aviation Medicine

The Main questions engaging the Institute of Aviation Medicine right up to its closure in April 1943, to judge from the published papers were: 1) the

pathogenesis of decompression sickness, 2) variations in the pressure of the spinal fluid under conditions of reduced barometric pressure and 3) certain problems in relation to the adaptation of the central nervous system to altitude.

Work on the pathogenesis of decompression sickness in fliers had been started at the Institute back in 1940 and was continued until 1943. A team consisting of Isakov, Milyagin, Rozenbl'yum and Skrypin was formed to work on this problem. In addition, Apollonov and Shik worked on the problems of nitrogen desaturation, which had a direct bearing on decompression sickness. These investigators established that during the first hour of breathing oxygen, both at normal pressure and at 8000 m, from 450 to 650 cc of nitrogen were liberated from the human organism, but that during an ascent to 4000 m (10 minutes) only 100 cc were eliminated.

Certain erroneous ideas about the etiology of decompression sickness were dispersed almost at once (oxygen deficit, provocation of rheumatoid diseases and so forth). From the very first the authors accepted the nitrogen etiology of decompression sickness and demonstrated its complete validity on 13 subjects particularly prone to the disease. These subjects were made to breathe pure oxygen for 3 hours before a pressure-chamber ascent. Ten out of 13 showed not the slightest symptoms of decompression sickness during 2 hours at altitudes of 10,000-12,000 m; in the other 3 the symptoms were only slightly expressed. In drawing this conclusion, however, the authors, far from implying that nothing more than the laws of physical chemistry was involved, attributed some importance to physiological factors as well (Isakov et al., 1941; Rozenbl'yum, 1943b).

Experimental demonstration of the nitrogen etiology of decompression sickness was provided by tests on goats kept at 9500-10,000 m for 3-4 seconds. Autopsy revealed general gas embolism, gas bubbles being particularly numerous in the subcutaneous mesenteric, portal and coronary veins. Gas bubbles were invariably found in the vascular synovia, rarely in the cerebrospinal fluid and occasionally in the pulmonary artery. The authors believed that this proved the "caisson etiology" of decompression sickness. At the same time, they concluded that the development of the symptoms did not correspond to the known Holden decompression coefficient (2.25) and that during altitude ascents the coefficient of permissible oversaturation was above 2.25.

Believing that biological factors (peculiarities of the blood and lymph circulation, peculiarities of the blood supply, hypocapnia and so forth) played a great part in the pathogenesis of decompression sickness the investigators paid special attention to the role of reflex influences emanating from the intestinal interoceptors. Ivanov failed to produce decompression sickness in fasting dogs but after a considerable drop in pressure he had only to blow the intestinal loop or the stomach to bring on a severe, fatal form of caisson disease, and the autopsies showed direct evidence of gas embolism of the vascular system. The disease did not set in after preliminary section of the vagus nerves under the diaphragm or of the splanchnic nerve. From this Rozenbl'yum concluded that "reflex influences emanating from the intestinal interoceptors played an

important part in the manifestation of caisson disorders" (Rozenbl'yum, 1943a). Ivanov had started studying the variations in the pressure of the cerebrospinal fluid, so as to discover the reason for attacks of vertigo at altitude despite a sufficient oxygen supply, as early as 1940. In an interim communication (1941) he reported his first data on the rise in liquor pressure when dogs and rabbits were raised to 9000 m. He subsequently established that the liquor pressure rose both in rabbits and dogs elevated to altitudes above 6000-7000 m. In man the liquor pressure started to rise at 4000 m. The rise in liquor pressure was less pronounced if oxygen was inspired at altitude. Inspiration of oxygen-impoverished gas mixtures caused the liquor pressure to rise but not so much as in altitude ascents. It was inferred that the rise in liquor pressure and consequently the rise in intracranial pressure was "the result of the simultaneous effect of reduced pressure and anoxia". An attempt to link the rise in liquor pressure with the variations in arterial and venous pressure under anoxic conditions produced no clear-cut results and Ivanov attributed it to a series of other causes (Ivanov, 1943a).

Adaptation of the central nervous system to altitude was studied by investigating the functions of so remote an analysor as the eye. The first attempt in this direction established the dynamics of photosensitivity of the eye after dark adaptation during repeated ascents to 5000 m. These investigations showed that on the first ascent the photosensitivity diminished sharply; during repeated ascents, however, this diminution became steadily smaller and at the sixth ascent was only very slight (Kruglyi, 1943).

The question of pressure-chamber training and its effect on altitude tolerance seems to have been dropped during the war, for not a single paper was published on the subject. The wartime article by Rozenbl'yum (1943d) on altitude adaptation was in fact a paper he had read in 1941.

The other problems of aviation medicine on which the Institute had worked so fruitfully before the war seem to have been similarly relegated to second place. This was partly because of the military situation near Moscow in the winter of 1941-42 and partly due to the organizational shortcomings of the Air Force medical service during the first period of the war. Another important factor was the loss of the Institute's former close links with people at the top level of the Air Force, who were now busy with urgent organizational and operational matters. Not until the end of the war did a few articles appear from the pen of some of the Institute's members, who had remained on the staff of the Central Aviation Hospital after the Institute was closed, showing that they were still assiduously working on problems of importance to aviation medicine under the difficult new conditions.

One of these articles was by Subbotnik (1945), who during the war continued his work on the use of stimulants such as cola; using a new technique for determining the effectiveness of stimulants by measuring the photosensitivity of the eye, which usually diminished at altitude, he demonstrated that if cola was taken, under conditions of hypoxemia (10.5 per cent oxygen) the photosensitivity remained normal. Caffeine, however, made it unstable. Subbotnik therefore concluded, as he had before, that cola was exceptionally important as a C.N.S. stimulant.

Another paper of this type came from Borshchevskii (1945), who discussed the examination of vegetative-vestibular disorders following a closed cranial trauma. After investigating 200 fliers who had suffered cranial trauma he was unable to discover in them any "visible labyrinthine disorders" by clinical examination; only by using the "cumulative method" did he detect vestibular-vegetative disorders in 70 per cent of them. He recommended that people suffering from slight or mild degrees of these disorders should be passed as suitable for flying but that those with severe disorders should be grounded for 3-4 months.

A noteworthy piece of work was done by Mirolyubov, Gurevich, Malyshkin and Spivak (1944) on gastric diseases in aircrew personnel. The interest of this work lay in the fact that the authors had worked out a fundamental formulation of the etiopathogenesis of certain diseases in fliers. They examined 98 men, hospitalized for 30-90 days with various diseases of the gastrointestinal tract. Despite the fact that the authors did not deny the "role of emotions, overwork, irregular and unplanned diet" in the etiopathogenesis of these diseases, despite the presence of "pronounced neuropsychic disorders" in many of the patients, despite the fact that many of the patients had become ill for the first time during the war or relapsed under field conditions (in particular, ulcers developed in 18 and reappeared in 15 of the 43 under active-service conditions) the authors completely excluded "any possible connection between the disease and the job", for they considered that "flying does not, on the whole, involve any special occupational health hazards". The authors were obliged to admit that 17 out of the 98 were completely unfit for flying, that 26 were only marginally fit, that the number and severity of gastric diseases in flying personnel was increasing during the war; yet they believed that there were "no grounds for connecting" these diseases with flying.

Lastly, one of the senior members of the Institute, Platonov, went on steadily working throughout the war. His paper on the classification of degrees of fatigue in aircrew (Platonov, 1944), although it contains interesting material, suffers from being somewhat schematic. He does not think a flier need be sent to the sanitorium unless he has a severe form of fatigue expressed as greatly-reduced efficiency, sleeplessness, sharp impairment of the mental activity and a number of vegetative disorders. All other cases of fatigue could be cured by sick leave or a period in a rest home.

Much more important was Platonov's compilation of a popular textbook on aviation medicine, Man in flight (1946), intended mainly for flying personnel. The author who had thought out this textbook long before the war and had flown as a pilot, continued working steadily on the book throughout the war and finished it at the front. He had set himself the difficult but rewarding task of "helping fliers to a better understanding of the effect of flight on the human organism". Written in a good, simple style and containing a great many excellent illustrations, the book gives a readily intelligible account of all aspects of aviation medicine. For the next ten years it deservedly remained the basic manual for trainees and fliers. Moreover, it was a new manual for many Air Force doctors who had come from the reserve without having any special university training in aviation medicine. One would not be far wrong in saying that for many years flight doctors based most of their practical work mainly on this book.

The appearance of this book was a major event in aviation medicine and showed Platonov to be a master of popularization as well as a man who had given all his energy and knowledge to the development of Soviet aviation medicine.

Strange though it may seem, no one on the staff of the Central Aviation Hospital, nor indeed of other aviation hospitals, paid much attention to publishing material on the medical examination of aircrews during the war. There was a wealth of data available on morbidity and traumatism in fliers, yet the intricate problems of examining fliers after trauma or illness received little mention in print. Not until 1945 was a new Manual on methods of examination for air medical boards issued, under the editorship of Sobennikov.

The Kirov Military Medical Academy

The Kirov Academy was evacuated at the end of 1941. The new conditions of work, under difficult circumstances, inevitably reduced the Academy's output: in 1942 14 research projects on aviation medicine problems were carried through, in 1943 only 3 and in 1944 7. The revival did not start until 1945, when the Academy carried out 15 research projects. The problem of anoxia continued as before to attract the attention of the departments of pathophysiology, normal physiology and biochemistry.

Petrov (1942) again raised in print the question of whether it was advisable to add small concentrations of CO_2 to the oxygen inspired at altitude.

In tests on mice breathing various concentrations of oxygen and carbon dioxide under normal atmospheric pressure he demonstrated the effectiveness of adding small concentrations of carbon dioxide (2.0-2.5%) under anoxic conditions and drew the conclusion that "during high altitude flights it is advisable to use low concentrations of carbonic acid". His error lay in assuming that the effects obtained under conditions of normal barometric pressure would be reproduced under conditions of reduced pressure. It was no accident that his proposal was not put into effect.

Danilov's study of gas exchange and tissue respiration during the after-effects of hypoxemia, started before the war, was reflected in a series of papers published in 1941, 1943 and 1947. All his tests on dogs and guinea pigs were aimed at studying changes in the oxygen and carbon dioxide absorption and in the tissue respiration after the animals had been kept for 5 to 48 hours at various altitudes. These investigations were of unquestionable value for study of the after-effects of prolonged hypoxemia, but they had no direct bearing on aviation medicine. Of much more interest in this respect were the positive variations in the gas exchange and tissue respiration of the liver after several ascents to altitude. Danilov regarded these changes as evidence of acclimatization to altitude. They persisted in his test animals for 15 days.

Petrov (1942) studied the variations in oxygen demand in animals with functional disorders of the central nervous system due to various degrees of anoxia, but obtained no definite data on the variations of the basal metabolism. Veselkin and Bykov (1946) studied the effect of massive blood losses on animals' sensitivity to altitude and concluded that blood loss did not reduce altitude tolerance. Aerial evacuation of wounded men who had suffered severe loss of blood was therefore permissible at 3000-4000 m. Conversely, thyroidectomy improved the altitude tolerance of rabbits (Veselkin, 1942). Vail' (1943), continuing his research on hypoxia tolerance of young animals, again found corroboration of the fact that "young mice possess much greater resistance to anoxia during the first weeks of life". He attributed this heightened tolerance to the poikilothermism of these animals but considered that further research was necessary to discover the reasons why young organisms should be more resistant to anoxia.

Investigations of the acid-alkali balance in the muscles and blood under anoxic conditions showed that whereas it shifted in the acid direction in the muscles a pronounced alkali shift was observed in the blood (Pelishenko, 1943). Vladimirov, using labelled atoms, determined the rate of penetration of phosphoric acid into the liver and brain under conditions of hypoxia and expressed certain views on the permeability of the tissue barriers under these conditions and on the significance of the phospholipid decay reactions. Investigation of the specifically dynamic effect of proteins at altitude showed that it was due to temperature conditions and therefore there were no grounds for limiting the amount of protein in the food rations for high-altitude flights (Alekseev et al., 1945).

The research done by members of the biochemistry department on metabolism under mountain conditions had prepared the ground for devising a diet for use in a high-mountain climate. It was found that for most people the total calorie intake at 4000 m should not exceed 3000-4000 and that the ration should consist of 120 g of protein, 80 g of fat and about 600 g of carbohydrates (Vladimirov, Grigor'ev et al., 1945). Such a ration, however, barely covered the actual energy losses involved in a mountain ascent, which according to Krestovnikov (1951) amounted to 600-800 cal. per hour. A ration containing only 3000-4000 cal. might well mean a deficit of 40-50 per cent for the mountaineer (Morozov, 1952).

Geiro (1947) once again discussed the advisability of using a carbohydrate-saturated diet under conditions of anoxia. He found that at 5000 m the blood sugar level rose in reasonably healthy people; but after an overload of sugar the hyperglycemic curve was at a higher level at altitude. Geiro considered that a carbohydrate diet improved efficiency at altitude and prevented untoward variations in the metabolism.

Several investigations of the visual function were performed. Study of the variations in the intraocular pressure showed an absence of strict parallelism between it and variations in the blood pressure, but after extirpation of the adrenal glands in animals the two curves were observed to follow a parallel

course (Lebedinskii and Bronshteyn, 1945). This suggested that the peculiar variations in the intraocular pressure (an initial rise followed by a drop) "must be connected with the ejection of adrenalin into the bloodstream".

Study of variations in the color-saturation threshold when oxygen-impoverished gas mixtures were inspired at 5000 m showed, unlike all previous investigations, that the sensitivity to red and yellow was improved and that the sensitivity to green and blue was greatly reduced (Mkrtycheva and Samsonova, 1944).

The normal course of the visual after-images was disturbed at altitude. At low altitudes of the order of 3000 m the duration of the after-image was extended but at altitudes above 4000-4500 m the duration of the after-image was found to be shorter and at the same time the latent period became longer. The duration of the after-image was found to be shortest in response to a green stimulus. The reduction in the duration of the after-image at altitude was due to "intensification of inhibitory processes in the visual analysor" (Aleksanyan, 1945). Investigation of the ratios between the external and internal musculi recti oculi showed that they were not affected even by severe hypoxia, but that even with slight hypoxia the duration of nystagmus was longer (Savin, 1946). At 6000 m the diameter of the pupil depended on the individual anoxia tolerance. In people resistant to altitude the pupil dilated; in people poorly tolerant of altitude it contracted; in people midway between these two groups it at first dilated but then rapidly contracted. No variations in the condition of the pupil could be detected when oxygen was inspired at altitude. Section of the oculomotor and sympathetic nerves caused no variations in the condition of the pupil at altitude but removal of the superior and inferior cervical sympathetic ganglia caused the pupil to dilate at altitude. Changes in the condition of the pupil were due to the influence of adrenalin (Tatarskii, 1942).

Under wartime conditions study of the effect of stimulants became important. The department of normal physiology did a great deal of work to discover the effect of phenomine on the various visual functions under replaced barometric pressure. It was demonstrated that under hypoxemic conditions phenomine reduced the chronaxy of the antagonistic muscles, relieved unpleasant sensations due to hypoxemia, improved the electrosensitivity of the eye, increased the latent period of the visual after-image, shortened the after-image time and improved the sensitivity of the visual apparatus in the process of dark adaptation (Volokhov and Zagorul'ko, 1944a-b).

Komendantov and Pivovarov studied the problems of training for rapid drops in pressure. Their aim was to devise a method of training which would enable the flier to perform rapid dives without any adverse effect on the middle ear. The data obtained from 462 man-ascents enabled them once again to confirm that such training was possible, a fact already known to flight doctors, and to devise two systems of training.

Most of the work was done in the pressure laboratory of the department of physiology, which was always open to anyone who wanted to perform experiments. Brestkin, the chief of the laboratory, was always glad to meet such people.

One piece of work done there was an investigation of the effect of pressure-chamber training on anoxia tolerance, by Barbasheva, Galitskaya, Ginetsinskii, Kuznetsov and Sergeev (1944). They verified, on 50 subjects, the effectiveness of the existing method of pressure-chamber training and concluded that it was unquestionably useful; but on considering why altitude tolerance improved after training they came to the conclusion that the reason lay not so much in somatic as in psychological adaptation.

Another investigation, by Chenikaeva (1945) concerned fluctuations in the carbonic anhydrase of the blood under reduced barometric pressure. The author concluded that under conditions of slight hypoxia, before pronounced hyperventilation set in, the carbonic anhydrase level of the blood always rose, but that in more severe hypoxia accompanied by acute hyperventilation it invariably fell.

All these works show that from 1940 onwards a whole series of departments in the Academy was involved in work on the problems of anoxia. Step by step members of the departments of normal physiology (Orbeli), pathophysiology (Petrov), biochemistry (Vladimirov), faculty therapy (Arinkin), eye diseases (Polyak) made interesting new discoveries breaking down, bit by bit, the wall of ignorance surrounding the phenomena lumped together under the title of hypoxia.

Particularly interesting was the work of a team in the department of normal physiology (Vinokurov, Levashev and Khromushkin), who worked under Brestkin's direction on a completely new problem, the influence of accelerations. The work was done jointly with the aviation research institute and was the first solid piece of experimental work in Soviet aviation medicine on this matter. It naturally attracted attention from Soviet flight doctors for many years. The authors issued several interim reports of their findings from 1944 onwards and in 1946 published a monograph New data on the effect of accelerations on the flier's organism (Vinokurov et al., 1946b). The authors made an important film on this subject. The interest of the monograph lies partly in the fact that the bulk of the investigations were performed during flight and partly in that they were studied from the angle of reactions of the central nervous system. The authors, following the erroneous postulates of Schubert (1937), completely rejected investigating reactions of the cardiovascular system. Their main conclusion, unquestionably of great importance, was completely new: "accelerations cause drastic disturbances in the activity of the central nervous system". These disturbances are expressed as a deterioration of the memory, an increase in the rate of response reactions, distortions of the sense of a given muscular effort and impaired coordination of movements. As a result, the pilot's efficiency deteriorates, for he applies either too much or too little force to the controls.

A second conclusion relates to the combined effect of acceleration and anoxia, causing "more deepseated visual disorders, greater disturbances in the coordination of movements, bigger errors in solving practical problems and much reduced rate of the response reaction".

Two further conclusions were exceptionally important. One was the contention that acceleration tolerance was improved if the pilot adopted a leaning-back posture. The other amounted to the statement that the disorders generated in the central nervous system during accelerations persisted for one minute after the acceleration stopped.

All these conclusions were of considerable practical importance and became firmly established in the canon of Soviet aviation medicine. If their authors had done no more, their work, which differed sharply in direction from that of authors in other countries, would still have represented an exceptional contribution to knowledge.

Unfortunately, the authors drew two more conclusions, which were not borne out in practice and with which Soviet flight doctors could not agree at all. One related to the mechanism of visual disorders under the effect of accelerations. The authors believed that in most cases such disorders "were due to mechanical shielding of the pupils by the upper eyelids", the weight of which increased in proportion to the strain. This conclusion had to be dropped as profoundly mistaken.

The second erroneous conclusion was that the processes occurring during rotation in the centrifuge were completely different from those occurring in flight and that "they cannot be taken as valid for practical flying purposes". This conclusion was to some extent responsible for holding up the production of centrifuges in the USSR and delaying experimental work on the problem of acceleration for several years.

An interesting contribution on acceleration came from Voyachek's department. Popov, in his thesis (1942), discusses the question of vascular reactions of the nasal cavity under the influence of acceleration. He established the important fact that during acceleration hyperemia of the nasal cavity is reduced in the cephalocaudal direction but increased in the caudocephalad direction. In animals, extirpation of the labyrinth produced no important modifications in this reaction.

Sobol' (1947a and b) showed that the threshold overload for the occurrence of the respiratory reactions under the effect of acceleration in the cephalocaudal direction was 0.3-0.9 g, but that for the caudocephalad direction it was 0.9 g or higher.

The Academy thus made a number of interesting discoveries on the effects of accelerations during the wartime.

Along with these major problems of anoxia and acceleration, the Academy worked on a series of other problems, for example aerial evacuation, prophylaxis against traumatism in pilots and the treatment of pertussis in pressure-chamber ascents.

As a result of tests on animals with open and closed pneumothorax, Goncharov and Elkhovskaya (1947) reached the conclusion that such wounds were not a contraindication for aerial evacuation at altitudes of 3000-3500 m, provided the patient was given oxygen. Petrov and Danilov (1946), as a result of observations on the course of cranial and brain wounds in animals, considered that it was permissible to fly people suffering from such wounds, even at 4500 m.

Pivovarov (1945) considered in detail various methods of protecting the flier against bullet wounds. Bulletproof chest guards, vests, helmets, elbow guards, back protectors, head guards, straps, masks and gloves suggested by various designers, flight doctors and fliers were subjected to thorough testing. The author rightly recommended against the attractions of palliatives and fought against the sluggishness of certain designers; the key problem was to protect the flier.

Vail' (1943) performed observations on the treatment of 20 children suffering from pertussis and subjected them to 2 to 4 pressure-chamber ascents to 3000-3500 m for 36 minutes. He concluded that the positive effect of this method of treatment was established only in three or four cases. He therefore considered it "inadvisable to continue tests on pertussive therapy by this method".

It seems, then, that the Academy did do a certain amount of research on aviation medicine problems, but that this work was somewhat diffuse. Its staff tackled any problem that happened to come along and did obtain certain experimental data, but there are no signs of plan, of clear aim, of any attempt to consolidate and develop the work. The only department that solidly and persistently worked on problems of aviation medicine was Orbeli's department of physiology, where the indefatigable and tenacious Brestkin, together with his immediate associates performed valuable new research on the effects of acceleration and pressure drops.

The Civil Aviation Scientific Research Institute

The vigorous prewar activity of the Civil Aviation Central Psychophysiological Laboratory was abruptly curtailed during the war. The laboratory itself underwent certain organizational changes. Many of its staff were mobilized and went to the front, the Laboratory was evacuated to Sverdlovsk and there turned into the Central Air Medical Examination Board, headed by

Samter. At the same time a Department of Aviation Medicine was opened in the Civil Aviation Scientific Research Institute and several members of the former Central Laboratory's staff were transferred to it. Professor Efimov was appointed as scientific consultant in physiology to replace Strel'tsov, who went to the department of aviation medicine.

The appointment of Efimov, who knew little about aviation, inevitably affected the work the department. Admittedly, he and a number of coworkers in the department did carry out six scientific projects even as early as 1942, but neither in subject matter nor in quality could they be compared with the research the same people had done under Strel'tsov.

The very first work produced by Efimov, Tolokonnikov and Gamburtsev (1942a), on the physiochemical and biological properties of the saliva under conditions of rolling, rotation and anoxia, must give the reader pause. Investigating the surface tension of the saliva in 60 subjects subjected to rolling on the swings, the authors noted a very marked fall in this index. Their only conclusion was that this was obviously connected with the intensified salivation accompanying the air sickness syndrome. Investigation of the surface tension of the saliva in 6 men (2 at 1500 m, 2 at 3000 and 2 at 4000 m) revealed only "slight" change. The surface tension of the urine also was found to alter "slightly". It is impossible to draw any concrete conclusions from these data.

In Efimov's next three communications, entitled Physiological effect of oxygen deficiency on the flier's organism, in which the reader might expect to find new data on this interesting question, he offers nothing new at all. The first paper (1942) gives data obtained from tests on 20 subjects who breathed gas mixtures containing 8-10% of oxygen. In addition to certain data on the quickening of the pulse and the variation in oxygen demand, the author reports contradictory biochemical changes, observed in only 3 of the subjects. He concludes that "hypoxemia weakens the nervous willpower, because of the exhaustion of the cortical nerve cells"; but his experiments gave him no grounds whatsoever for this conclusion.

The next two papers were on "comfortable altitudes for passengers during long flights". This was a little nearer to practical requirements and must certainly have been of interest both to civil aviation and to the bomber command. The investigation had followed three lines of enquiry: first the effect of a 4-hour stay at the pressure-chamber equivalent of 2000, 3000 and 4000 m was studied; then a 4-hour flight was made at 3000 m with four people aboard; finally 63 passengers were questioned and examined after long flights at 1000-3000 m.

The pressure-chamber investigations revealed the following changes in the physiological functions: 1) oxygen demand fell in some of the subjects but rose in others; 2) pulmonary ventilation was reduced (?); 3) "respiratory excursions" diminished; 4) vital capacity was reduced; 5) the acid-alkali balance shifted in the direction of alkalosis at 4000 m, though not in all the

subjects; 6) bicarbonates were detected in the urine of some subjects; 7) at 4000 m the reticulocyte count rose, but in some cases a "degenerative neutrophilic shift" occurred, with inpairment of the visual memory and "reduced capacity to work at maximum tempo".

Observations on the general conditions of the subjects showed that they withstood 4 hours at 2000-2500 m but that their general condition deteriorated in the second hour at 3000 m and that at 4000 m it deteriorated even in the first hour. From this it was inferred that for most passengers an altitude of 3000 m without oxygen was "uncomfortable" (Efimov, Tolokonnikov, Gamburtsev et al., 1942b).

During the experimental 4-hour flight at 3000 m the general condition worsened in all four subjects after two hours, at the end of the fourth hour the subjects were suffering from headache, pallor, cyanosis, general weakness, impairment of memory and deterioration of the visual accommodation. Again, the conclusion was that 3000 m was "uncomfortable" for most people.

From the observation on the 63 passengers it was concluded that a 3-hour flight at 1000-2000 m inevitably induced fatigue; one hour's flight at 3000 m involved no fatigue but a longer flight at this altitude caused the general condition to deteriorate, particularly in children, old people, subjects with cardiovascular insufficiency and people suffering from influenza or malaria.

The authors' general conclusions can be summarized as follows: 1) flights at 2000-2500 m are "comfortable" for four hours for most passengers but for weaker people flights at this altitude should be limited to two hours; 2) a flight at 3000 m can be regarded as "comfortable" for one hour; 3) a flight at 4000 m is "comfortable" for only 20 minutes (Efimov et al., 1942).

All these data are certainly interesting and if the work had been carried further they would have made a valuable contribution to aviation medicine. Unfortunately, the work was dropped for some reason, and the data given above can be regarded only as a first step in the study of this important problem.

The scientific activity of the Central Air Examination Medical Board amounted to little more than the work of its chief, Samter. He devoted the first three years of the war entirely to working on his own immense volume of material covering 28,000 examinations of aircrew personnel during the period 1933 to 1944. He consolidated his accumulated experience in a doctorate thesis on The theory and practice of medical examination of flying personnel in civil aviation (1944). This book was undoubtedly a major event in Soviet aviation medicine, for it was the first thorough coverage of all the problems of aircrew examination. With great clarity the author insisted, for the first time, on the importance of the individual approach to assessing the state of health of a flier, drew attention to the necessity for detailed study of his efficiency indices and pointed out the great importance of systematic observations by the flight doctor on the state of health of aircrews. The main purpose of

the work was to "help examiners to get away from the meretricious 'fit-unfit' formula and to resort more often to differential selection for particular types of flying".

The ten chapters of Samter's book, covering in great detail all the medical specializations involved in aircrew selection, show that he had made a thorough study of the subject. In each case his approach is to trace the development of views on the importance of this or that standard and index in assessing the fitness of a flier, and to this end he draws on the world literature on the subject. Any flight doctor faced with the necessity of deciding whether a man is fit for flying will find in Samter's book the answers to many questions arising in the course of examination, with a clear indication of the value of various methods of investigation and an account of the step-by-step search for the best methods. It is to be regretted that because of wartime conditions it was published in a limited edition and so prevented from becoming widely known.

The book reflects the development of Samter's own views on selection questions. He had started his scientific career in 1932 as a psychophysiologist and for years he urged the use of psychotechnics in the selection and training of fliers. Gradually, however, he lost his enthusiasm for this approach; his work now revealed profound disappointment with the methods of psychophysiological selection and showed that he had completely abandoned them. "Modern psychology does not possess a single effective technique for establishing a prognosis of flying aptitude", he writes (p. 109) and "at its present level psychology is incapable of opening the doors of the flying school to anyone at all" (p. 110); and further: "most psychological methods of selection are ineffective" (p. 109).

Also of great interest are Samter's views on the organism's reaction to flying. Like a number of other authors, he bases his views not on the state of health of people who have left the profession but on that of people who are still flying; in other words, he does not take into account the factor of natural vocational selection and therefore his propositions suffer from a certain one-sidedness. Nevertheless, they are very characteristic. He is a categorical opponent of the theory that a man can exhaust his flying aptitude: "Once and for all I have repudiated the theory of exhausted flying aptitude" (p. 113). His reason is apparently that "the proportion of flying personnel suffering from diseases of the nervous system is extremely small and the proportion grounded for this reason is even smaller" (p. 63); "adverse psychogenic conditions are found in fliers no more frequently than in other professions" (p. 71) and "even temporary incapacity due to nervous diseases is extremely rare among fliers" (p. 72).

Samter was equally against attempts to associate any other diseases specifically with flying. He writes, "for the most part, the ear, nose and throat diseases which have led to unfitness for flying have not been due to the job itself" (p. 18); "in only 2 per cent of all cases has the reason for grounding been vestibular vegetative disorders" (p. 19). Although he did not express an

opinion in regard to internal diseases, he reached the conclusion that "flying has no effect at all on the organism" (p. 124).

This was the view of people working at the Institute of Aviation Medicine (Kulikovskii, Mirolyubov, Samukhin, Sobennikov, Subbotnik and others) and we must regard it as a basic proposition in Soviet aviation medicine at a particular stage in its history. Samter's book is then seen as its clearest expression.

Strel'tsov and his work

I have already mentioned that in 1939 the Peoples' Commissariat of Health decided to reorganize the department of aviation medicine attached to the Central Institute for Further Medical Training and to organize an aviation medicine department at the Second Moscow Medical Institute, where a faculty of aviation medicine was organized as well. Strel'tsov was head of both. The organization of the first two departments of aviation medicine in the Soviet Union called for immense efforts on his part. He had to draw up the first syllabuses and compile the first textbooks on teaching method, select lecturing staff, equip his laboratories and install pressure chambers. At first all this held up the scientific work of the departments and of their chief. Nevertheless in 1940 Strel'tsov published five papers on, among other things, the effect of high-altitude flights, overstrain, and anoxia on the central nervous system.

The most interesting of these was his 1940 paper on The nature of pains developing during high altitude flight, in which he casts doubt on the nitrogen etiology of decompression sickness and advances a number of new ideas on this problem. After studying the data from 5000 man-ascents to altitudes above 10,000 m he reached the conclusion that the incidence of altitude pains was not higher than 7 per cent. After tests on several subjects who had first breathed oxygen for 20 minutes to 3 hours he concluded that preliminary oxygenation did not yield positive results. This compelled him to look for other causes of decompression sickness and he suggested: 1) increased tension in the joint capsules and ligaments, causing stimulation of the nerve endings, 2) disturbance of the osmotic pressure in the synovia, 3) heightened sensitivity to pain under anoxic conditions, 4) irritation of the joints by cold and 5) isothermal and adiabatic processes of gas expansion. He did not come out definitely in favor of any one of these reasons but thought further research essential. As we know, this showed that the nitrogen theory was the only correct one.

Another of Strel'tsov's works (1941c) concerned the digestion and diet during high-altitude flights. After a general review of digestive and metabolic disorders under conditions of oxygen deficiency, for which he used the data of Razenkov, Vladimirov, Sirotinin and others, Strel'tsov attempted a theoretical rationale for the flier's diet. His basic propositions can be summarized as

follows: 1) take-off must not be permitted until 1 1/2 hours after breakfast or 3 1/2 hours after a main meal, so that the stomach should be relatively empty before take-off; 2) the diet must contain a considerable amount of carbohydrates, the amount of protein must not be below normal levels; as for fats, cream, sour cream and butter must be compulsory items of diet but fat pork, mutton and goose must be excluded; 3) the vitamin C intake must be increased.

In a long article on The prophylaxis of hypoxemic conditions in aviation (1941b) Strel'tsov discusses not only the question of prophylaxis but also the improvement of altitude tolerance. He is not enthusiastic about using drugs for this purpose. "I have taken another path", he says: he meant pressure-chamber training. He equates the changes in physiological functions produced in high-mountain ascents with those produced by inspiring oxygen-impoverished gas mixtures or by pressure-chamber ascents. He gives preference to the latter, but his final conclusion is unfavorable: "mass training in the pressure-chamber does not always produce the desired effect"; the only effective method, in Strel'tsov's opinion, is individual training.

A work that must have attracted attention among flight doctors was Strel'tsov's Twenty-five years of aviation physiology and medicine in the USSR (1942b), important as the first historical work on aviation medicine to be written in the Soviet Union. This is not a complete chronicle of all the research done but simply an account of the basic trends in Soviet aviation medicine. Strel'tsov's picture is one of initial enthusiasm for psychotechnics on the part of Soviet aviation doctors, followed by gradual disillusionment with these methods and a switch of attention to the solution of physiological problems. He gives a detailed account of the work done by Voyachek's collaborators and of the research on the effect of anoxia on the central nervous system and the analysor functions. He brings out his own basic idea that anoxia disturbs the phylogenetically younger functions before the phylogenetically older functions. Here he again asserts that the addition of CO_2 to the oxygen inspired at altitude would have a favorable effect. The remaining problems of aviation medicine are treated more superficially, but the whole article shows Strel'tsov's conviction that the achievements of Soviet aviation medicine during the twenty-five years had contributed a great deal to the wartime combat fitness of the nation's aviators.

The majority of the works listed have a review character but they clearly reflect Strel'tsov's basic ideas about the effects of oxygen deficiency. Alongside his review works Strel'tsov continued his experimental work, in conjunction with his new colleagues, during the war. As before, his attention was particularly drawn to disorders of the analysor functions. Together with Dorodnitsyna (1942) Strel'tsov attempted to discover the mechanism of changes in the photosensitivity of the eye at altitude. After investigating the photosensitivity of a dark-adapted eye to ipsilateral and contralateral illumination he came to the conclusion that at 5000 m, as a result of anoxia, the "normal

interactions and interrelationships in the central retinal representatives" were the first to suffer. In a second work, jointly with Tarasenko (1942) he broke new ground by asking whether disorders similar to those produced in the pressure-chamber could be produced by the conditioned-reflex method. The subject of study was the variations in the renal functions (quantity of urine, its specific gravity, presence of bicarbonates, free acidity, ammonia, phosphorus and organic acid level). The investigators were convinced, "to our own surprise", that even one simulated ascent to altitude (after three or four preliminary real ascents) elicited the same changes in the renal function as actual "ascents". These conditioned-reflex reactions gradually faded out after nine or ten simulated ascents but one more real "ascent" was sufficient to restore them completely. The possibility of producing conditioned-reflex changes, by confirming the leading role of the cerebral cortex in producing a series of vegetative reactions at altitude, was an extraordinary discovery and Strel'tsov was the first to make it, not only in the USSR but in world aviation physiology. It is still not quite clear why an investigator of Strel'tsov's standing did not concentrate longer on this question; one would have thought that he had all the right conditions for a whole series of brilliant experimental investigations.

But during the war Strel'tsov's attention was diverted to the compilation of a number of pamphlets on the effect of altitude and accelerations on the human organism, which he issued under the title For the aviation doctor. These pamphlets, of course, were essential for our flight doctors, most of whom were unable to get any specialized training in aviation medicine at all during the war and the fact that so eminent an investigator as Strel'tsov undertook this popularization work does him credit.

Only later (1944) did he return to experimental work, when he studied, jointly with Fedorov, the effect of certain pharmacological preparations on the acuity of vision under conditions of reduced barometric pressure. He made some extremely interesting discoveries. It was found, for example, that the acuity of vision was not fully restored by breathing oxygen at altitudes above 10,000 m nor by breathing oxygen after one hour at 4500 m; that phenamine improved the acuity of vision at altitude and that ascorbic acid, tartaric acid, caffeine and methylcaffeine had the same effect. Combinations of ascorbic acid with phenamine or methylcaffeine were particularly effective in this respect (Strel'tsov and Fedorov, 1944).

This was Strel'tsov's last experimental work but one. Last of all (1946 and 1947) was an investigation, jointly with Khazen, on the activity of carbonic anhydrase under conditions of reduced barometric pressure. All his remaining works are of a review character. Another major work was his editing of the translation of van Liere's Anoxia (1947).

On 1 July 1947, Strel'tsov, who had long suffered from diabetes, gave himself a large dose of insulin. In a severe state of hypoglycemic coma he was taken to hospital, where his condition was taken for hyperglycemic coma

and the duty doctor gave him a further dose of insulin. The result of this medical error was the premature death of this outstanding investigator and ardent champion of the right of Soviet aviation medicine to a place of its own among the scientific disciplines.

Other Scientific Research Institutes

Before the Second World War the problems of aviation medicine interested only a few scientific research institutes. During the war patriotic duty impelled many institutes and departments to take up subjects of military importance. The gradual achievement of mastery in the air and the brilliant victories won by Soviet airmen kept public opinion aware of the Air Force, and most research institutes and departments started to work on the problems of aviation medicine. It would be tedious to review all the work of all the research institutes thus engaged during the war and I shall confine myself to enumerating those principally involved and indicating the questions on which they worked.

1. The Pavlov Physiological Institute of the Academy of Sciences: Ginitsinskii and Barbasheva continued to work urgently on the theory of tissue acclimatization to reduced atmospheric pressure. Studying the reactions of mountain sheep to altitude they satisfied themselves that these reactions differed substantially from those of lowland sheep. The blood oxygen capacity and the respiration remained unaltered, but the oxygen pressure in the blood was lower at altitude. The authors concluded that in mountain sheep the process of adaptation to altitude consisted in adaptation of the tissue processes to the changed environmental conditions. They found confirmation of this when they studied the tolerance of altitude-acclimatized animals to cyanide poisoning. Apart from this, Ginetsinskii, Samter and Natanson (1944) studied the use of phenamine as a specific against flying fatigue and Chenykaeva (1945) studied variations in the carbonic anhydrase level under conditions of reduced atmospheric pressure.

2. The Central Institue of Ophthalmology: Bogoslovskii and Kravkov (1941) worked on the effect of aero-engine noise on the visual function and Shcheglova studied the effect of reduced atmospheric pressure on the intraocular pressure.

3. The Ukrainian Institute of Experimental Medicine: Domontovich (1941) investigated the effect of reduced atmospheric pressure on experimental anaphylaxis and Karavanov (1941) studied the prophylaxis of altitude sickness by blood transfusion.

4. The Department of Physiological Chemistry of the All-Union Institute of Experimental Medicine: Kaplanskii (1941) took up the question of blood transfusion for improving altitude tolerance and jointly with Fridlyand (1945) investigated the blood histamine level under conditions of reduced atmospheric

pressure. Vaisfel'd (1945) studied the diaminoxidase level in the tissues of animals under conditions of anoxia.

5. The Institute of Labor Protection: Kandror determined the pattern of nitrogen desaturation in man.

6. The Department of Pathophysiology of the Central Institute of Advanced Medical Training: Krasovitskaya, Strel'tsov and Syrkin (1945) studied the carbonic anhydrase activity under various conditions.

7. The Department of Physiology of the Second Moscow Medical Institute: Margulis, Ur'eva and Slavikovskaya (1941) determined the regulating properties of the hematoencephalic barrier in hypoxemia.

8. The Institute of Nutrition: Molchanova studied the effect of repeated subjection to reduced atmospheric pressure on the metabolism and acid-alkali balance.

9. The Naval Medical Academy: Fedorov (1942) studied the effect of narcotics on altitude tolerance; Zasosov (1944) studied the illusion of contrary rotation; Rikkl' and Krivosheenko (1944) studied the effect of phenamine on the human organism under conditions of anoxemia; Kurtsin and Nekrasov (1942) investigated the effect of rapid atmospheric pressure drops; Sergeev (1946) studied variations in the tone of the cardiovascular system in trainee pilots.

10. The Leningrad Neurosurgical Institute: Orlovskii and Mal'm studied the effect of reduced atmospheric pressure on animals with trauma of the abdominal cavity; Revyakin (1941) investigated the results of aerial evacuation on men suffering from bullet wounds to the central nervous system.

11. The Department of Pharmacology of the Second Moscow Medical Institute: Skvortsov (1941) worked on the problem of pharmacotherapy under anoxemic and anoxic conditions; Shvarsalon (1945) studied the effect of benzole and benzine on the organism under reduced barometric pressure.

12. The Department of Pathophysiology of the Khar'kov Medical Institute: Al'pern and Berger determined the presence of mediators in the blood of animals at altitude.

13. The Bogomolets Institute of Experimental Biology and Pathology: Sirotinin (1941) and his coworkers continued urgently studying the effect of anoxia on the various physiological processes.

14. The Kazan' State Institute of Medicine: Zikeev (1941) studied variations in the intracranial pressure under conditions of reduced atmospheric pressure.

15. The Uzbek Institute of Experimental Medicine: O.N. Pavlova (1944) studied the climatophysiology of the cardiovascular and hematopoietic systems under conditions of various altitudes in the Pamir Mountains.

16. The Department of Psychiatry of the First Moscow Medical Institute: Gurevich, Sumskaya, Khachaturyan (1941) made an attempt to treat depressive conditions of hypoxemia.

17. The Bekhterev State Institute of the Brain: Zyuzin (1942) continued studying the problem of roll in aircraft and in this connection investigated the significance of the functional conditions of the cardiovascular system.

18. The Central Pediatric Institute: Karganova attempted to treat pertussis in children by high-altitude flights.

19. The Department of Pharmacology of the All-Union Institute of Experimental Medicine: Kuvatov (1941) studied the effect of vegetative poisons on the condition of the pupil under high-mountain conditions.

20. The Ukrainian Institute of Labor Hygiene and Occupational Diseases: Sukhovii(1941) studied the condition of certain psychophysiological functions at 9000 m, using oxygen apparatus.

21. The Morphological Laboratory of the All-Union Institute of Experimental Medicine: Lazovskii started investigating morphological changes occurring during anoxia.

22. The Department of Pathophysiology of the Second Leningrad Medical Institute: Uzhanskii (1945) continued work on Bogomolets's theory on the significance of erythrocyte decay under reduced pressure in the problem of blood regeneration.

23. The Moscow Brain Institute: Parfenova and Livanov (1945) studied changes in the cortical action currents at various altitudes.

24. The State Institute of Physiotherapy: Moshkov and Tsimmerman (1941) worked out a new method of physical exercise for training the vestibular apparatus in fliers.

There is no space here for even a brief account of all this research. The mere enumeration of the topics investigated shows how deeply the war had involved the Soviet medical community in the problems of aviation medicine, and there can be no doubt that the subject was greatly enriched by experimental research on a wide range of questions. Most of these were purely theoretical matters, mainly concerned with the effect of reduced barometric pressure, but each of them contributed something new to the basic problem of aviation medicine, anoxia. This gave aviation physiology a sound theoretical basis and the flight doctor a solid scientific foundation for his daily work.

The Work of the Flight Doctors

The research done by Soviet flight doctors was an important contribution to aviation medicine. Solidly grounded in day-to-day practice, its subject-matter was invariably drawn from the routine work of ensuring the combat fitness of the flier. This alone gives it special interest, for the record of scientific research done by flight doctors shows the extent both of their general training and qualifications and of their interest in aviation medicine, and how they tried to apply its theoretical propositions in practice.

The research done by rank and file flight doctors in the prewar period has already been fairly vividly described. During the war, with the recruitment of reserve medical officers without specialized training, it fell off to some extent, but despite the wartime difficulties many flight doctors found it possible to work on one or other of the ever-urgent problems of aviation medicine.

Most of this work took the form of special reports, individual observations and rationalization proposals for improving the conditions of life and work for aircrews. The wartime difficulties made it impossible to publish these works and a wealth of practical observations and conclusions remained unknown to the majority of flight doctors. Some of the larger base hospitals and the medical services of particular armies and fleets sometimes printed symposia containing scientific observations and investigations by flight doctors. These were published in limited editions and I have not managed to track down all of them; some of the work done by flight doctors therefore receives no mention in this book.

A study of Soviet aviation medicine based solely on published works would show that the research output of rank-and-file flight doctors during the war was high; I have found fifty-seven papers in the periodical press alone.

The conditions under which the Soviet Air Force was operating during the war, mainly at comparatively low altitudes, meant that such problems as altitude sickness and anoxia received comparatively little attention from flight doctors. Nevertheless, certain individual investigations and observations deserve mentioning.

Vokhmyanin's work (1942) on the clinical picture and practical field diagnosis of altitude sickness is particularly noteworthy, because the disease often develops while the flier is at altitude and these cases usually escape the flight doctor's attention. Describing a series of interesting cases of the onset of altitude sickness during flight, Vokhmyanin recommends that such cases should be detected by interrogating and examining pilots immediately after landing. The interrogation should cover the flier's feelings while in the air, his report on the performance of the oxygen apparatus, his own assessment of the performance of his mission (bombing results, finding bearings, performance

of navigational calculations), the nature of the entries in the log, the handwriting, the landing and so forth. In the examination the most important point was to take the pulse, since bradycardiac effects would, in the author's opinion, indicate that altitude sickness had been contracted.

Finkel' (1941), in a short note, gives his own observations on the early symptomatology of altitude syncope. He found, on the basis of 6000 man-ascents, that at 5000 m syncope more often than not occurred in the first 20-30 minutes at that altitude; the precursors were slowing down of the pulse, disappearance of facial hyperemia, pallor and nausea. Badmas and Isakov (1943) give a whole series of practical counsels on the use of oxygen apparatus in prolonged flights at medium altitudes.

Klimov (1945) produced an interesting work on the variations in arterial and venous pressure in man at various altitudes. His data showed that on ascending to 5000 m the arterial pressure rose by 20-45 mm, but that the venous pressure, although rising at 1000 m, fell below the initial level at higher altitudes. Unfortunately, the author limited himself to investigating four men and did not continue his work.

In some cases aviation doctors engaged in purely experimental work. Esipovich, for example (1941), made a series of tests to study the reflex activity of the spinal cord under conditions of reduced atmospheric pressure. He studied the variations in the flexor reflex in cats after section of the spinal cord at the level of the first lumbar vertebra and found that inhibition of this reflex occurred as low as 1500-2000 m, was particularly marked at 7000 m and completely suppressed at 8000 m. In adducing these data, the author unfortunately draws no general conclusions.

A. P. Popov's work on the effect of prolonged oxygen inspiration at altitude in guinea pigs belongs to this category too. He found no sign of any change in the mucous membranes of the upper respiratory tracts after the animals had breathed 80-82% of oxygen for 3-5 hours daily for a month at altitudes of 8000-10,000 m.

Another piece of experimental work in the same group was Naumov's study of variations in the gastric function at 9000 m in 7 men breathing oxygen. His findings were as follows: 1) evacuation of the stomach contents at altitude was accelerated in 5 men and slowed down in 2; 2) the amount of gastric juice diminished in most of the subjects; 3) acidity of the juice was reduced in most of the subjects; 4) the digestive power of the juice was reduced in most of the subjects. In view of the fact that in all these cases the oxygen supply was adequate the author concluded that "the inhibitory effect of altitude must be attributed to reduced barometric pressure. Reflex effects due to distention of the stomach and intestinal walls by the increased volume of gases in the abdominal cavity must be regarded as the most probable mechanism of the inhibitory effect of altitude".

The effects of accelerations, despite their ever-increasing importance in aviation, were not a subject of discussion in the work of flight doctors. The only known work on the subject is by Knabengof, Dantsig and Simonyan (1943). These authors, starting from the fact that variations in hydrostatic pressure occur as a result of acceleration and that the blood supply to the abdominal organs is increased, set themselves the aim of studying the hemorenal interrelationships, relying on the data on depuration, diuresis and urea content in the blood. The investigation was performed on 10 men before and after a flight involving a great many aerobatics. The results were fairly varied: after the flight, depuration increased in 6 men and diminished in 4. The authors were inclined to regard the very slight variations in diuresis and depuration as indicating "good tolerance of overstrain".

Little appeared in print on the medical aspects of ensuring combat efficiency. The subjects of discussion in most cases were methods of introducing fliers' personal health record books, the order of selection for posting to rest homes, health education of fliers and so forth. Such questions were discussed in print by Gromov, Dolbnin (1941b and 1942) and others. Popov (1945) gives the general account of the work done by the Air Force medical service to ensure combat fitness. Vinogradov (1941) gives information on the first-aid kits used in the Polish and Japanese Air Forces.

Several papers were written on problems of aerial evacuation. The most detailed was by Kaktysh (1942), but this related only to the winter of 1941-42 and dealt only with light, short-range aircraft. The author found that under these conditions such machines were a highly effective means of transport. In the first ten months of the war "many thousands of wounded" were evacuated in such aircraft. As evacuation flights were at altitudes not higher than 1000 m he did not once observe any "deterioration in the condition (of the wounded) en route. Men suffering from abdominal, chest, craniocerebral and other wounded withstood the evacuation well".

Apart from the evacuation of sick and wounded, aircraft were widely used for transporting medical supplies. Khrenov (1941), on the basis of experience in the early months of the war, worked out two methods of unloading medical supplies from aircraft: 1) when landing was possible, 2) when landing was impossible. For the latter case various types of packing were devised for dropping the supplies with or without parachute. Unfortunately, the results of using these methods in practice were not published.

A completely separate question was that of the work of aviation-medicine laboratories during the war. Before the outbreak of war, as I have said, the aviation-medicine laboratories of the Army Air Force were abolished but those of the Naval Air Arm remained and continued their work throughout the war. Basically, this work amounted to periodic examination of flying personnel. The laboratories worked mainly on the dispensary system. During the war they were situated in the immediate neighborhood of a principal air unit or a field hospital

or a rest home. This gave them opportunity for extensive observations on healthy, convalescent and sick fliers and also ensured continuous liaison with the air units, partly though regular consultation with the flight doctors, partly though periodic conferences. The latter were either purely informative, for the purpose of acquainting flight doctors with new advances in aviation medicine, or for exchange of day to day experience among flight doctors and laboratory workers. For every flier attending an aviation medicine laboratory for treatment or consultation a case history card was opened. This card was additional to the personal health book and remained in the laboratory. During the war the laboratories accumulated 1500 [sic] such cards and started working on them "from various points of view".

The existence of the Naval aviation-medicine laboratories and their work in the field of medical examinations provided an opportunity for discussing the special medical selection of naval aircrew personnel. A pamphlet was issued in 1945, under the editorship of Strel'tsov, Aristov and Shishov, containing personal reports by a number of flight doctors and recommendations on procedure for aircrew examination. Shishov describes the battle experience of fliers in various types of naval aircraft and sets out the requirements in regard to the condition of the nervous system in aircrew personnel. Belskii discusses in detail the requirements as regards the condition of the internal organs, Mikhailov the requirements in regard to the organ of vision, Zasosov the requirements in regard to the otorhinolaryngological organs; Kantorovich expounds a procedure for psychological examination of aircrews and Totrov deals with the organizational aspect of medical boards. An appendix contains a guide to the medical requirements for various types of flying duties and a medical chart showing the reasons for failing a candidate.

The procedural instructions and health recommendations given in this pamphlet served as a good basis for the examining work of the military laboratories.

Morbidity in fliers during the war, as well as traumatism, was covered by the periodical press. Nevertheless, some flight doctors found time to communicate their own observations. Dolbnin (1941a), for example, raised the very acute problem of wartime neuroses in fliers. Although his classification of neurotic conditions cannot be regarded as fully satisfactory, his practical conclusion, to the effect that rest homes must be organized on the basis of military hospitals, was very important.

A work by Marshalkin (1945) on asthenia prophylaxis in fliers is of very great interest. The main factor responsible for neurotic disorders in fliers, in the author's opinion, was the cumulative effect of slight forms of hypoxemia, inevitable at high altitude when the KP AZ-bis oxygen apparatus was used. He believed that the most efficient prophylaxis would be to go over to oxygen apparatuses of the "automatic lung" type. Of the other possible prophylactic precautions, he found systematic medical observation, diet, physical culture and stimulants in the form of phenamine and cola the best. Despite the

fact that the author attributes asthenia in fliers to the special nature of their work, he suggests that "there are no grounds at all for regarding this as an occupational pathology".

The largest amount of work done by flight doctors was devoted to the ear, nose and throat. Pukhal'skii (1941) investigated the effect of pressure-chamber training on the ear, nose and throat organs. Out of ten subjects he obtained good results in 5, satisfactory in 3 and poor in 2. Mikhin (1941a), on the basis of investigating 140 fliers, reached the conclusion that men with cicatricial modifications of the tympanic membranes should not be taken off high-altitude high-speed flying. But he found 15 out of 500 (3%) suffering from pain in the sinuses on landing. Acute rhinitis was detected in all these men. Akopodzhanyan (1941) criticized the existing anti-noise equipment. Rakhmilevich (1941a) described 2 cases of rupture of the tympanic membranes in fliers during dive bombing and Ivanov (1941) reported 5 cases of inflammation of the accessory sinuses of the nose in pilots flying without goggles and connected these diseases with chronic cold. Rukhman (1941) reported his experience in training the vestibular apparatus in 26 candidates on swings and concluded that the training gave very good results. Rakhmilevich (1941b) published data on the effect of hypoxia at 5000 m on the vestibular analysors on 120 fliers; he found no significant functional deterioration.

The physical training of the flier, despite its immense importance in maintaining his combat efficiency in wartime, was not much discussed among flight doctors. There is only one paper on the subject, by Tkachenko (1941), where the author complains that the situation in the units is unsatisfactory in this respect and urges its improvement.

The work of the flight doctor under combat conditions was another subject which was not adequately treated in print. Pukhal'skii (1941a), at the very beginning of the war, did ask "what is a flight doctor?" and insisted that the flight doctor must have not only a training in physiology and hygiene but also a clinical specialization. This extremely important question, however, was not discussed in print. The only article on the matter to be published at any time during the war was a brief account by Leenson and Golikov (1942) describing the flight doctor's work under combat conditions.

There was even less published discussion on the training of medical assistants for air units, despite the considerable importance of their work in keeping aircrews medically fit for combat. A series of works by Shavtsov (1941a, 1942 etc.,) is therefore particularly noteworthy. In simple language the author explains the physiological implications of high-altitude flight, the operation of oxygen apparatuses, the effect of accelerations on the flier's organism, the purpose of pressure-chamber training, the diet required by fliers before high-altitude flights, the basic principles of airfield medical servicing in wartime and so forth. Anxious to do everything he could to popularize aviation medicine Shavtsov published a pamphlet entitled What the flier should know about the effect of altitude flights on the organism (1941a).

The war record of Soviet aviation medicine is one of steady development and improvement. There were immense difficulties due to the war itself; there were organizational shortcomings in the Air Medical Service; the Institute of Aviation Medicine, for all its importance, was closed and a great research center, the Kirov Academy, was evacuated far into the interior; the trained corps of flight doctors was diluted with an influx of doctors from the reserve, without any training in aviation medicine; yet despite all this, lively research yielded a wealth of new experimental data and aviation medicine was enriched by the practical experience rank and file flight doctors acquired in the field. Soviet aviation medicine reached a new level during the war and entered the postwar period with correspondingly bright prospects for its future development.

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